PinMap

A tangible interactive map
visualizing city health

MONTEM

AALBORG UNIVERSITET
STUDENTERRAPPORT

RESUMÉ

Problemstillingen i dette bachelorprojekt omhandler at designe en installation, som skaber en bevidsthed om forurening og gøre det nemt for den almene borger i Aalborg at forstå den fremviste information. I samarbejde med virksomheden MONTEM vil projektgruppen gennem dette projekt gennemgå adskillige iterationer. I løbet af disse iterationer vil projektgruppen undersøge forskellige designs og teste elementer fra disse designs gennem prototypes tests.

For at løse problemstilling har projektgruppen designet en installation med navnet PinMap, hvilket fokusere på spatial visualisering og informering af byens helbred i Aalborg, rettet mod den generelle befolkning. Installationen giver information omkring gas, støj og partikler, hvor resultatet kan modificeres dynamisk i forhold til ændringer af forurenings situationer og tidspunkt på dagen. Alt data til installationen er hentet gennem et produkt som hedder CityProbe, hvilket er udviklet af MONTEM til at monitorere adskillige parameter i bylivet, heriblandt de udvalgte forureningskilder.

Den initiale idé blev valgt ved hjælp af et idékatalog, som blev lavet til at facilitere et møde med MONTEM. Idékataloget bestod af seks idéer, hvilke blev genereret ud fra retningslinjer, dannet under introduktionsmødet med MONTEM.

PinMap bliver gennem projektet raffineret ved at drage inspiration fra relateret arbejde, to prototype test og en brugercentreret evaluering. I relateret arbejde bliver der undersøgt tre emner i form af museums installationer, public displays og tangibles. Ud fra research fra relateret arbejde blev projektets problemformuleringen raffineret til at inkludere brugen af spatial visualization metoder til at kommunikere information til brugeren.

Projektgruppen gennemgik herefter flere iterationer, hvor der blev produceret og testet tre prototyper. Den første prototype handlede om at udforske konceptet PinMap. Her blev både kortet, pindene til at interagere med og feedback testet. Denne test viste en problematik i forhold til brugernes forståelse af feedbacken. Ud fra denne viden blev feedbackfokusset for anden prototype test. Her blev der fokuseret på forskellige feedback typer, og hvordan brugernes perception af disse typer forekommer. Ud fra denne test fandt projektgruppen frem til, at interaktionen mellem pind og kort skulle være i form af en magnet og at der skulle bruges lys, samt vibrationer til feedback. Herefter gik projektgruppen i gang med at lave en tredje prototype, som var ment til at være en high fidelity prototype af installationen. For at forberede den tredje prototype tog projektgruppen ud på Aalborg Hovedbibliotek for at undersøge lokationen og snakke med brugerne af stedet. Dette var med til at skabe to personaer, som blev brugt til støtte udviklingen af den tredje prototype, samt inspiration til opsætningen af prototypetesten. Ud fra evalueringen som fandt sted på Aalborg bibliotek kunne projektgruppen konkludere, at brugerne havde nemt ved at forstå installationen, og de forskellige niveauer af forurening, som blev visualiseret gennem installation. Det var dog ikke oplagt for brugerne, at de kunne interagere med pindene på map'et. Evalueringen indikerede, at installationen havde en virkning på brugerne, og de blev oplyst omkring forureningen i byrummet.

TABLE OF CONTENTS

Background	This chapter contains an overview of the collaboration with MONTEM and the presentation of the problem scope this project works within.
Related work	Research on related works will be conducted and explored to draw inspiration to our project.
Problem refinement	In this chapter, the related works will be discussed based on weaknesses and strengths.
Method	In this chapter, an introduction to the next three chapters will be made, where a description of how the iterative model has been used throughout this process will be explained.
The first prototype	This chapter contains further development of the concept and a test of the first prototype.
The second prototype	In this chapter, we did a further development of the concept, where a test was made focusing on how users perceived different feedback methods.
The third prototype	In this chapter, we will include results from the previous prototype test and make design choices for the installation. Through observations and interviews with users, personas were created, and the prototype refined.
Evaluation	The installation will be evaluated based on the data gathered through a user study at Aalborg main library.
Discussion	Discussions and reflections will be made upon the prototype processes, user involvement, location, and awareness.
Conclusion	Conclusions will be made on the problem statement to see if it lives up to the project statement

INTRODUCTION

In this bachelor project, an integrated interaction design solution was developed in cooperation with MONTEM. The project is focusing on using spatial visualization to inform the general population in Aalborg about city health through interaction design. This project uses a user-centered approach, where the goal is to create awareness for the general population of Aalborg about the different pollution levels in their environment.

The project group has chosen to provide information about gas, noise, and particle pollution since these have the most significant impact and consequences for human health (Mst.dk, 2019). There are 3400 premature deaths in Denmark per year due to unhealthy levels of pollution in the environment (Dinhverdag.astma-allergi.dk, 2019).

“More than making beautiful things, the design should be asking questions about how it can positively impact the world around us.” - William Drenttel (Design Indaba, 2019).

Throughout this project, we have worked on designing an installation that creates awareness of pollution, to make it easily understandable for the general population of Aalborg. In order to achieve this, spatial visualization methods have been used to communicate information.

A motivational aspect for choosing this problem area and working with MONTEM was the interesting aspect of designing a user interface that visualizes data in an alternative way using spatial visualization. Aalborg University bought 50 CityProbes, to gather data about various parameters. This data is currently used for academic research purposes and is not visible for the general citizens of Aalborg. From this, a question arises;
would the common citizens of Aalborg understand the data measured and what that data means if it were to be visualized?

The project group found it interesting to explore if a spatial visualization of the data would make the general population aware of the health of their city. The project group found the case exciting and challenging due to the many possibilities and limitations.

BACKGROUND

1

This chapter presents the exploration of the case provided by MONTEM, see appendix 1. The focus is to create a user interface through spatial visualization that communicates information to citizens. In this chapter, the collaboration with MONTEM will be described with additional research regarding the effects of pollution in the urban environment. The first meeting with MONTEM will be outlined, and their additional guidelines will be defined. Through this, an idea will be presented, which will be the foundation for the further development of a design.

1.1 Collaboration with MONTEM

MONTEM is a company that focuses on creating and developing intelligent infrastructures for different sectors on a municipal and national level. They are specialized in developing research-based, high resolution, and low-power sensor networks for digitizing existing infrastructure (Montem.io, 2019).

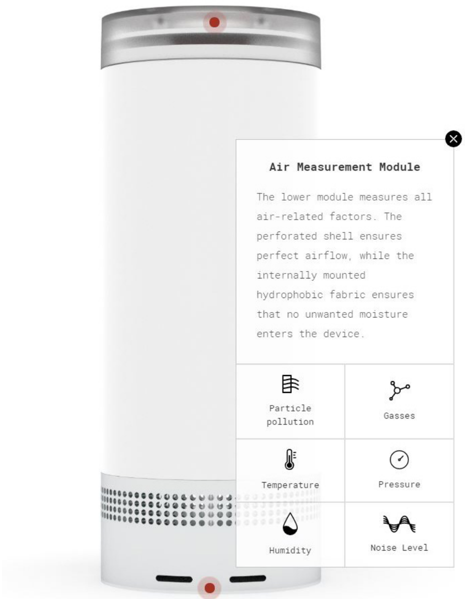


Figure 1.1: Render of the CityProbe (Montem.io, 2019)

MONTEM has designed and developed CityProbes, which are the fabric of the intelligent city. These CityProbes gather data about the air quality, climate and other data points, such as noise, gas levels, particles, rain and light/UV index, *see figure 1.1* (Montem.io, 2019).

The probes are designed for the urban environment and are being deployed in cities around Denmark, where each probe transmits the state of the environment from in real time. The data collected from the CityProbes can be viewed in real-time in a control center; the CityFlow see figure 1.2. The CityFlow visualizes all incoming data from the CityProbe network and indicates of the cities well being (Montem.io, 2019).

Figure 1.2: MONTEM's CityFlow (Montem.io, 2019)

User interfaces for visualizing SmartCity information

The main focus in collaboration with MONTEM was to develop a concept, which should enlighten the general population of Aalborg about the city's health. MONTEM preferred the project group to follow a human-centric approach to design an user interface with the focus of creating a meaningful experience while making their data more digestible for the citizen of Aalborg.

This has to be achieved by using spatial visualization to communicate information to the citizens

1.2 Refining the design case

To further understand and refine the design case, the project group arranged a meeting with MONTEM, with the focus of defining the specifications for the project. Guidelines were defined to explicitly describe the overall conceptual limits for the project in collaborating with MONTEM.

- **Allow citizens to interpret their everyday environment**
- **Information and understanding is a key parameter**
- **Create awareness about pollution**
- **Communicate information that is understandable for the general population of Aalborg**
- **Focus on using spatial visualizations to communicate information to the citizens**

With the established guidelines and the design case in mind, an initiating problem statement was created to form a more narrow scope for the process.

Initial problem statement

"How can we develop a solution, which creates awareness about pollution using spatial visualization and gives the general population a deeper understanding and information about city health."

1.3 Exploration of the scope

It was interesting to explore the impact the parameters, measured by the CityProbe, have on the environment and the city health. To create a scope for the project to design within, the project group focused on air and noise pollution, since these types of pollution have the most negative impact on the environment and individuals.

MONTEM measures two kinds of air pollution; gas levels and particles. The CityProbe measures two kinds of gas levels, these being nitrogen dioxide (NO2) and Carbon monoxide (CO), and two sizes of particles, PM2.5 and PM10. PM2.5 is fine particles measured below 2.5 micrometers, and PM10 is a more coarse particle measured below 10 micrometers and above 2.5 micrometers. In addition, the CityProbe measures noise in decibels (dB) (montem.io, 2019).

1.3.1 Air pollution

Air pollution is harmful to individuals and the environment. Transport and wood burning stoves are the two most common sources for pollution in Denmark, where 67% of PM 2.5 particles come from stoves, and 72% of the nitrogen pollution comes from transport (Mst.dk, 2019).

In cities where there is much traffic, high concentrations of air pollution appear.
Particularly cars and busses play a part in this, by polluting the air at low amplitude, where a large density of population is located. In densely trafficked areas and narrow streets with high buildings, pollution can reach high concentrations that are harmful to the health of people. (Dinhverdag.astma-allergi.dk, 2019).

The limit value for PM10 is 40 µg/m3 on average per year, and the limit for PM2.5 is 25 µg/m3 on average per year (Envs.au.dk, 2018). For NO2, the limit is 40 µg/m3 on average per year and the limit value of CO is 10.000 µg/m3 as the largest 8-hours moving average over a year (ibid.).

Studies show that air pollution can have an impact on the health of people over a long period. In Denmark, air pollution is responsible for many health issues, *see figure 1.3* (Mst.dk, 2019).

- 3400 premature death
- 3.4 million sick days
- 595 hospital submissions
- 506 cases of lung cancer
- 285 cases of heart failures

Figure 1.3: Danish health issues caused by air pollution (Mst.dk, 2019)

1.3.2 Noise pollution

Road traffic is the most widespread source of noise pollution in populated areas (Mst.dk, 2019). The limit value of noise in residential areas, such as residential buildings, day care centers, and outdoor living areas are 58 decibels from road traffic and 64 decibels from train traffic.

Road traffic affects individuals health negatively, and according to the Danish Environmental Protection Agency, an estimation between 800 and 2200 people in Denmark are annually admitted to hospitals with heart disease and high blood pressure, as a cause of traffic noise (Mst.dk, 2019). The report assessed that road noise causes 200-500 premature death as a follow of high blood pressure and heart diseases.

According to WHO, the World Health Organization, traffic noise can cause nuisance and consequences to health (Mst.dk, 2019). These are illustrated in *figure 1.4.*

- Headaches
- Difficulty sleeping
- Increased risk of heart disease
- Communication difficulties
- Hormonal effects

Figure 1.4: General health issues caused by traffic noise (Mst.dk, 2019)

It became clear that air pollution and noise have a great impact on the environment. It was therefore important for the project group to design a concept, which creates awareness about the pollution levels, particles, gas and noise in the environment. With MONTEM's and the project group's conceptual guidelines for the project, user-centered research began, where the project group explored how to design an experience and create awareness of the initial problem.

1.4 Idea catalog

An idea catalog was used as a communication tool to express the perspectives and visions for the project. The tool should make it easier to communicate feedback and ensure insight into the thoughts and visions for the project. To see the full idea catalog, *see appendix 2.*

Based on the initial problem, six ideas were created and presented for MONTEM. These ideas were based on awareness about pollution in the city for the general population, using art installations, augmented reality, dynamic shaping, and tangible user interface.

MONTEM gave the project group insights about the positive and negative aspects of the presented ideas and a more narrow scope to work within.

MONTEM and the project discussed the ideas and decided to make further development of one of the ideas presented in the idea catalog. In agreement PinMap was the selected idea because it had the most potential based on the case description. MONTEM agreed on the scope, which the project group found interesting to explore in this project.

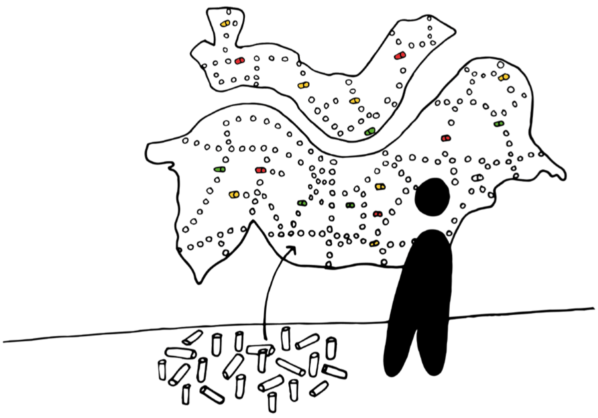


Figure 1.5: An illustration of the idea, PinMap

1.4.1 Sketches of PinMap

This idea takes form as a tangible interactive map of the city, Aalborg, with interchangeable pins, each representing a parameter, *see figure 1.6*. The pins can be placed on the map and will give feedback in the form of light. The pins each represent; *Gas level, Noise, and Particles.* Users can, therefore, choose a pin and place it at any location on the map and will then receive feedback in the form of the intensity of the pollution that occurs at the specific location. The parameters will each be represented with several pins, which makes it possible to compare different places at once, and to let multiple users participate at the same time.

1.5 User experience

In order to create a memorable experience for the users, when interacting with the product, it is important to consider how the users' mind works (Kucheriavy, 2019). In this project, the focus was on creating awareness for the users, while interacting with the design. The vision for the project is to enlighten the users about the initial problem, which is described in section 1.1.2, *Refining the design case,* and it was, therefore, important that the information was memorable and easily perceived. People have a working memory, where information is perceived, and can only hold limited information before it is forgotten again (ibid.). This is also known as short-term memory. When people are paying attention and trying to remember something important, as in long-term memory, a simple distraction can cause the information to be forgotten. It is, therefore, important to keep the users focused on one thing at the time, and the distractions should be minimal. The focus of the design should fit the person's needs and interests.

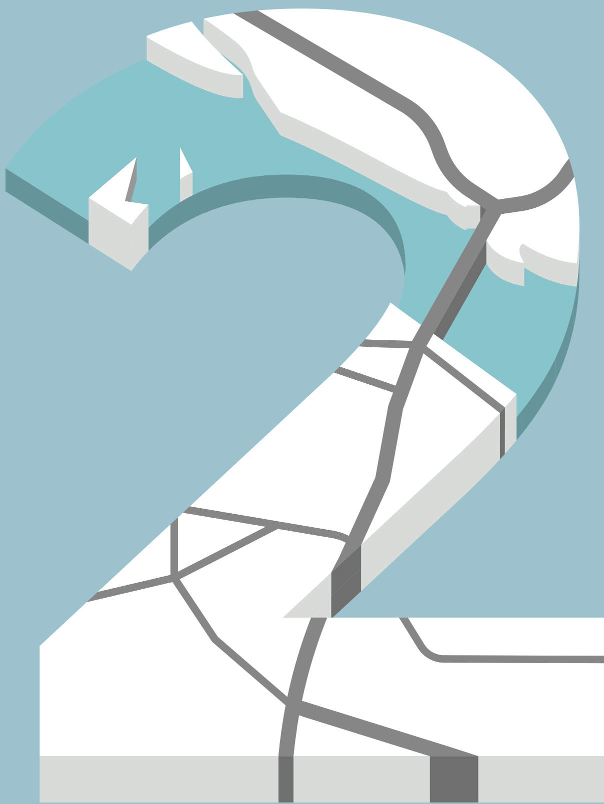
It is also important to consider the amount of information given. In this project, the focus is on visualizing CityProbe data using spatial visualization, which makes it relevant to focus on how much information will be available for the users and how many options they have. There are many theories on the “magic number” for how many items people can remember, but four items seem to be the most promising. Another important aspect to consider is people recognition of elements (Kucheriavy, 2019). People have a higher memorization rate if they can recognize specific colors to which they associate with something known (ibid.). These are some of the considerations the project group will keep in mind during the design process of the further development of PinMap.

It was important for the project group to create awareness for the citizens regarding city health. According to the Merriam Webster dictionary, awareness is "The quality and change of being aware. Knowledge and understanding that something is happening or exists." (Merriam-webster.com, 2019). With this in mind, we wanted to create a design that makes the general population aware of the pollution levels in Aalborg and to let them understand the changes in the city regarding pollution. Dhaval Vyas stated that the awareness information derived by design should be open for interpretation, be easily understandable, and should not make decisions for the users (Vyas, D. 2011). Therefore, we wanted to create a design that does not tell the users what to do, but provide them with information that they can use and interpreted as wanted, to make the users aware of the problems.

1.5.1 Summary

At this point in the process, the project group had some background knowledge about the initial problem the project focuses on. The idea that came out of the knowledge works as a foundation for a future concept. What the project group does know, is that the idea must create awareness about pollution, and transmit it in an understandable way, where it focuses on visualizing *Particles, Gas, and Noise* in specific locations around Aalborg. In the next chapter, related work will be researched, to create a broader knowledge about alternative ways to visualize pollution.

RELATED WORK



The related research that informs our work, is broadly comprised of Museum installations, public displays and tangible user interfaces. Within museum installations two installations were explored by working with gas and particles, and in public displays the implications of fear and embarrassment were explored. With tangibles the project group explored how a tangible interface could be developed, and what benefits that might have.

2.1 Museum installation

With technology being utilized more in museums, they have become a popular research ground for Human-Computer Interaction research and technology deployment (Hornecker and Ciolfi, 2019). Museum installations are places for exploration of ideas and creative display of information and artifacts (ibid.) Museum installations are interesting to explore, since the focus of this project is also to display feedback to the users in a manner that is understandable to a broad audience.

2.1.1 Mutual Air's "Bell"

Figure 2.1: The Mutual Air "Bell" displayed at Oakland Museum (Oakland North, 2019)

Mutual Air's Bell was an exhibit that launched September 30th at the Oakland Museum of California made by Rosten Woo, *see figure 2.1* (Mutualair.org, 2019). The project had a time span of 6 months and there were thirty "Bells" with chimes across Oakland reflecting disparities in air quality around them through auditory feedback (ibid.). It detected the PM 2.5 particles in the air around the Mutual Air exhibition as well as detecting the CO2 in the earth's atmosphere.

The chimes were used to reflect PM 2.5 particles, few chimes every minute were considered normal, but fast chimes every second or more indicated a larger amount of particles (Mutualair.org, 2019). During the afternoon the chimes will start clicking, these clicks reflects the global CO2 level in the earth's atmosphere.

2.1.2 Particle Falls

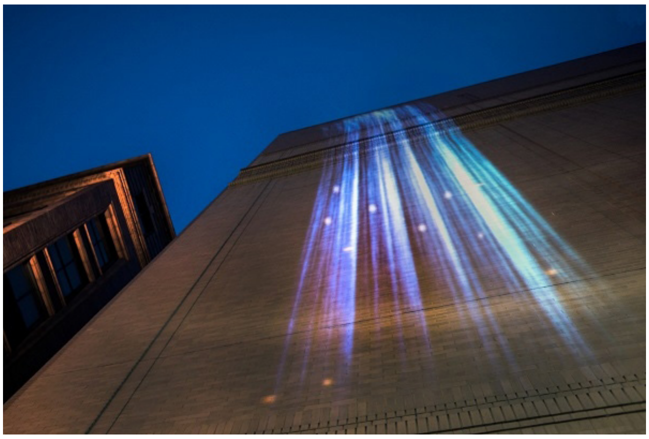


Figure 2.2: "Particle Fall" by Andrea Polli (Pittsburgh Art Places, 2019)

Particle Fall was made by Andrea Polli and was displayed at the Wilma Theater in Center City Philadelphia. Andrea Polli used a projection of falling blue light with fiery colors and crackles to represent the particulate matter, detected by a nearby air monitor, *see figure 2.2* (Science History Institute, 2019). Andrea Polli wishes to draw attention to particles surrounding the citizens, which may affect the health, by displaying microscopic threats in the air and it aims to be a way to learn about the quality of air around the citizen (ibid.).

The installation used increasing frequency to indicate a higher concentration of particles, and the projected image updated every 15 seconds with new data. Particle Fall visualized PM2.5 particles that were measured by a Nephelometer (ibid.).

Both of the presented installations aim to create awareness for PM2.5 particles which are damaging to the health. The two installations use two different techniques to display information, Rosten Woo's "Bell" having two different tones depending on what data is presented and use an increase in frequency of tones to display more pollution. Andrea Polli's "Particle Fall" projects light in order to reflect the particles in the vicinity of the installation. In this project we also aimed to use feedback to reflect particulate measurements, amongst other types of pollution through a physical platform, not using standardized methods, such as graphs on a computer screen.

2.2 Public display

Public displays are rapidly overtaking the public space, where they add new elements to the existing environment (Müller et al., 2010). This is partly achieved by replacing old signs with interactive displays, these displays could be placed anywhere in the public space, but are often placed in urban environments, malls or shopping windows. Public displays can be interactive displays that require direct haptic interaction, but could also be displayed containing motion trackers.

The placement of public displays are challenging, when trying to attract the users attention (Müller et al., 2010). The public space can be cluttered with other technological noise, which makes the competition for the attention difficult. The success of the display is depends on attention, however creating too much noise in the public space is not ideal. Public displays also need to focus on the users' needs, and avoid creating an embarrassing experience in the public space. This is crucial in terms of avoiding exposing the user and challenging their social role.

Successful public displays encourage interaction, and the interaction often starts before the user actively interacts with the display (Müller et al., 2010). This is achieved by the display picking up passersby, which can be used to manipulate the environment. This could be done by adding a funny hat, change the context from a room to a beach or similar changes (Kin Design, 2019). The interaction with the display can also start by the display making noise to draw attention from the passerby.

2.2.1 The Opinionizer system

The creators behind the Opinionizer system wanted to create an interaction with a public display, which required very little effort (Brignull and Rogers, 2003). They were interested in how to overcome the fear of an embarrassing situation occurring, so the users would participate. Trying to achieve this goal, they created the Opinionizer (ibid.). This was a public display that encouraged users to add their opinion about various topics. The purpose was to come up with small comments, that did not require much effort. Moreover it should be clear, that there was no obligation to take part, and people could observe, if they felt more comfortable with this, *see figure 2.3.*

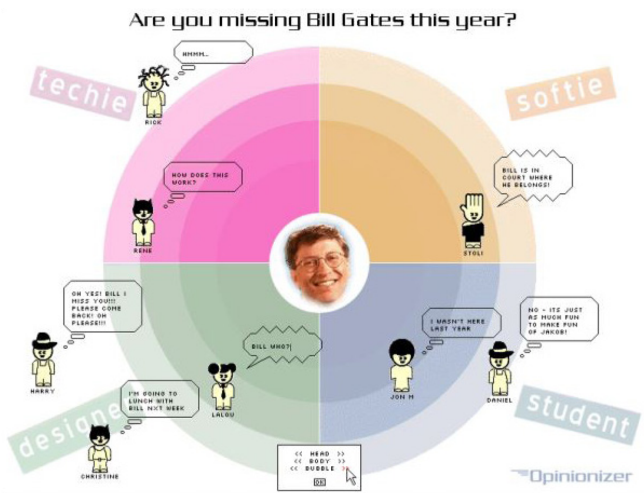


Figure 2.3: The Opinionizer system (Brignull and Rogers, 2003)

The Opinionizer was placed and organized in a way, that made it more socially acceptable, by adding multiple tables nearby and inviting people to comment on their neighbours interaction with the display (Brignull and Rogers, 2003). This encouraged mingling and conversation between strangers.

Testing the public display, it was placed in two different settings (Brignull and Rogers, 2003). One at a book launch party, another at a welcome party for new students at a university. Similar for both events, none of the people participating in the party interacted with the display. Eventually some people interacted, and tried to invite others to do the same. However people were hesitating, since they did not know what the display was about, and they did not want to commit too much effort towards it.

As the events became more crowded, a honeypot effect occurred (Brignull and Rogers, 2003). As more people were forced to stand closer to the display, they could start observing what was on it, which lead to conversations about the display. Eventually people reached the level that they wanted to participate and encouraged others to do the same. Interviewing the participants afterwards, there was both positive and negative feedback (ibid.). The positive feedback revolved around the topics on the display being interesting and the lightweight interaction. The negative feedback was about the socially acceptable aspect. The participants commented that they felt awkward about being observed, and that they felt a pressure about writing something socially acceptable.

To solve the problems, the researchers suggested adding offline comments, or simply anonymous comments to the Opinionizer (Brignull and Rogers, 2003). Moreover a lot of the guests participating in the two events did not interact with the display. They only observed from a distance, and the encouragement to participate was never there. This could be solved by making it clear how the participants would benefit from the interaction

2.3 Tangibles

One of the initial guidelines from MONTEM, see chapter 1, Introduction, was, that the product should use spatial visualization. With this in mind, the project group found it interesting to research tangibles, and how they could support spatial visualization of data.

Tangibles can be in the form of a physical technological object, that uses sensors and can be accessed through at least one of the human senses (Price, 2008). This type of technology enables new ways of interacting and creates a different kind of experience with new forms of engagement (ibid.).

When a user is interacting with the tangible, a sensor is registering the interaction, which is communicated to a computer system (Preece et al., 2015 pp. 207). The system uses the registered interaction to create output for the given tangible. This output could be in the form of sound, light, vibration or similar.

2.3.1 TUI: GaussBits

Tangible user interfaces gives the user access to control and understand digital information in a different way, where they also get access to direct manipulation of the information (Liang et al., 2013).

At the CHI Conference in 2013, a group of researchers presented a paper, which focused on this digital manipulation using magnets. Previously only 2D manipulation on displays with physical artifacts were possible (ibid.). One of these 2D manipulators were Wacom, which used an electromagnetic field to track the drawing pen. This 2D limitation encouraged a team of researchers to explore the above-surface possibilities using magnets on non-touch LCD displays and tablets.

GaussBits, which is the tangible object that the researchers produced, contained a magnet on the inside (Liang et al., 2013). This allowed various designs for the GaussBits, with the only limitation being that it had to contain the magnet, and that it may not be produced out of ferrous combinations. The reasoning for this limitation, originates from how the magnetic field may get affected by the ferrous, which would lead to a limited range.

The purpose of GaussBits was to create 3D manipulation, in terms of a near-surface interaction with tilt and roll (Liang et al., 2013). This was fulfilled by implementing a thin-form Hall-sensor grid on the back on non-touch LCD display or tablet, which could then capture the magnetic stylus. The grid was able to track the north and south polar field at the same time, which enabled the tilt and roll positioning, *see figure 2.4*.

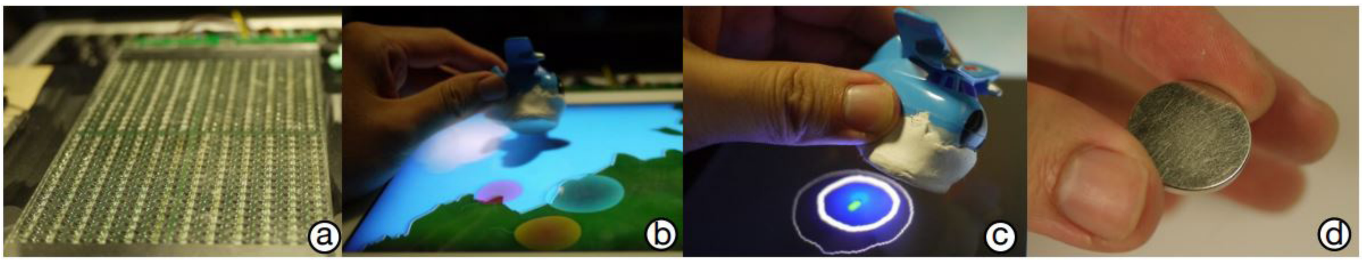


Figure 2.4: Gaussbits, the grid, alternative usage (Liang et al., 2013)

These tangible objects have some limitations, due to the short range on the magnets (Liang et al., 2013). However if you were to add stronger magnets and increase the sensitivity on the Hall-sensor grid, it might be possible to expand the current range for the magnets. The current range for GaussBits varies from 17 to 44 mm, and does not support a full set of 6 degrees of freedom.

With the exploration of the related works in mind, the project group will discuss and evaluate the research, with the focus of creating a refinement of the problem statement for the project. The discussion can be seen in chapter 3. *Refinement of the problem.*

PROBLEM REFINEMENT

3

While there has been much focus on installations in the previous chapter, which reflects the disparities in air quality, visualization of particles surrounding the citizens and social interactions, there has not been sufficient research on spatial visualization of data. With this in mind, the project group started exploring how to design an installation, which focuses on spatial interaction and visualization of data.

Based on the guidelines, the project group worked with awareness, spatial visualization, interaction with the user, and understanding feedback and its effects. Each of the related works gave insights into the subjects, but they also had weaknesses. Mutual Air's "Bell" and Particle Fall did not have any explanation on how it worked, and people had to interpret the meaning of the installations for themselves. Both Bell and Particle Fall did not create any interaction between the observers and the installations.

The Opinionizer contained a weakness based on the social aspect of the interaction. The users needed to provide personal opinions, but they felt that their opinions must be socially acceptable. This is a weakness in the design because it would make the users feel forced to behave in a certain way. Other than that, the enforcement of acting in a certain way would result in an unpleasant feeling while being observed while performing the interactions.

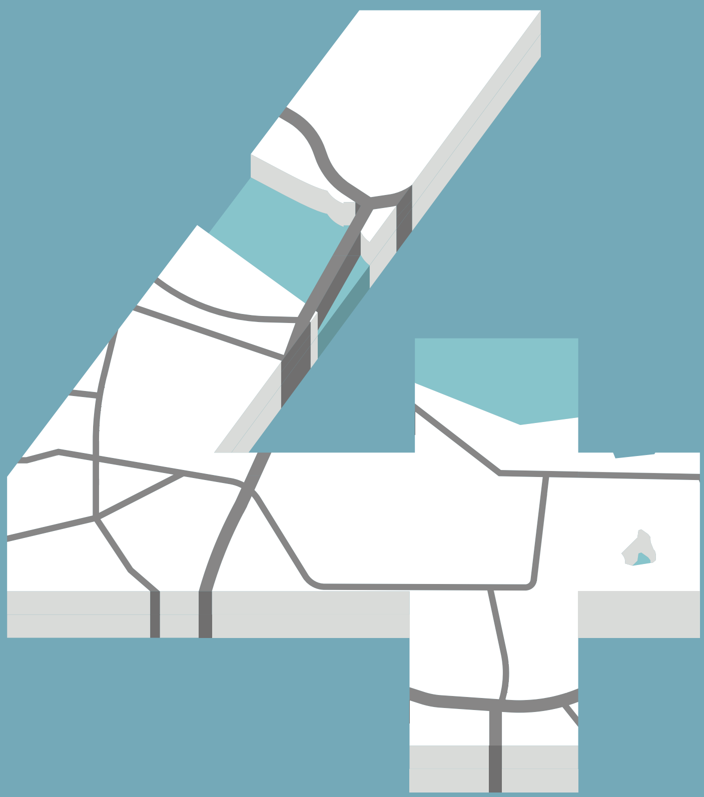
Looking at the related work, they all contributed with new and different insights, useful to the project. The museum installations both focused on visualizing data of pollution in alternative ways, by using light and sound. What is also interesting about the museum installations is that their audience is the common citizen, which also makes the way they mediate the exhibitions relevant for our project.

Public displays Falls slightly outside our scope since we are interested in working with alternative ways for visualization, more specifically, spatial visualization. However, many elements about public displays were still relevant to the project, which is why we decided to explore the topic. Public displays are accessible to the general public, as our installation is supposed to be. The challenges public displays experiences might also be relevant for our project, due to the setting being used.

With the exploration and research of related works, the project group got an overview of different installations and products which explore the initial problem. It was interesting to research on other installations and become aware of existing interactions, with our initial take on this project in mind. Due to the weaknesses of the related works, it was interesting to explore how to visualize data in an alternative way through spatial visualization. There were none of the related works, which focuses on spatial visualization specifically, so the project group decided upon to work with the following problem statement:

"How can we design an installation that creates awareness on pollution, that is easily understandable for the general public of Aalborg to interpret their everyday environment, by using spatial visualization methods that communicate information about city health?"

METHOD



In order to investigate how to develop a physical interactive installation that supports the needs of the citizens of Aalborg, several methods were used. Through sketching different designs where explored, whereas a prototype was build to test with users. Gathered data from the test will be analyzed and new requirements will be established and used for further iterations. During the process, three iterations were conducted, resulting in a high fidelity prototype, which will be evaluated with stakeholders.

4.1 Simple Lifecycle Model for Interaction design

During the following three chapters, the project followed the simple lifecycle model which is an iterative process model, *see figure 4.1*. The model consists of four activities of interaction design, in which three are user-centered. (Preece et al., 2015).

The first of the four phases is "establishing requirements" (Preece et al., 2015). These requirements could be the clients providing a set of requirements or the result of an evaluation.

The second phase is "designing alternatives", in this step the design team would develop different alternatives, which could be a possible direction or solution to the problem space. These design alternatives would be based upon the requirements established earlier or they could be derived from prototyping or the evaluation of the prototype.

The third phase is the prototype development. Prototypes are developed from the designs decided upon further testing during the previous step "design alternatives".

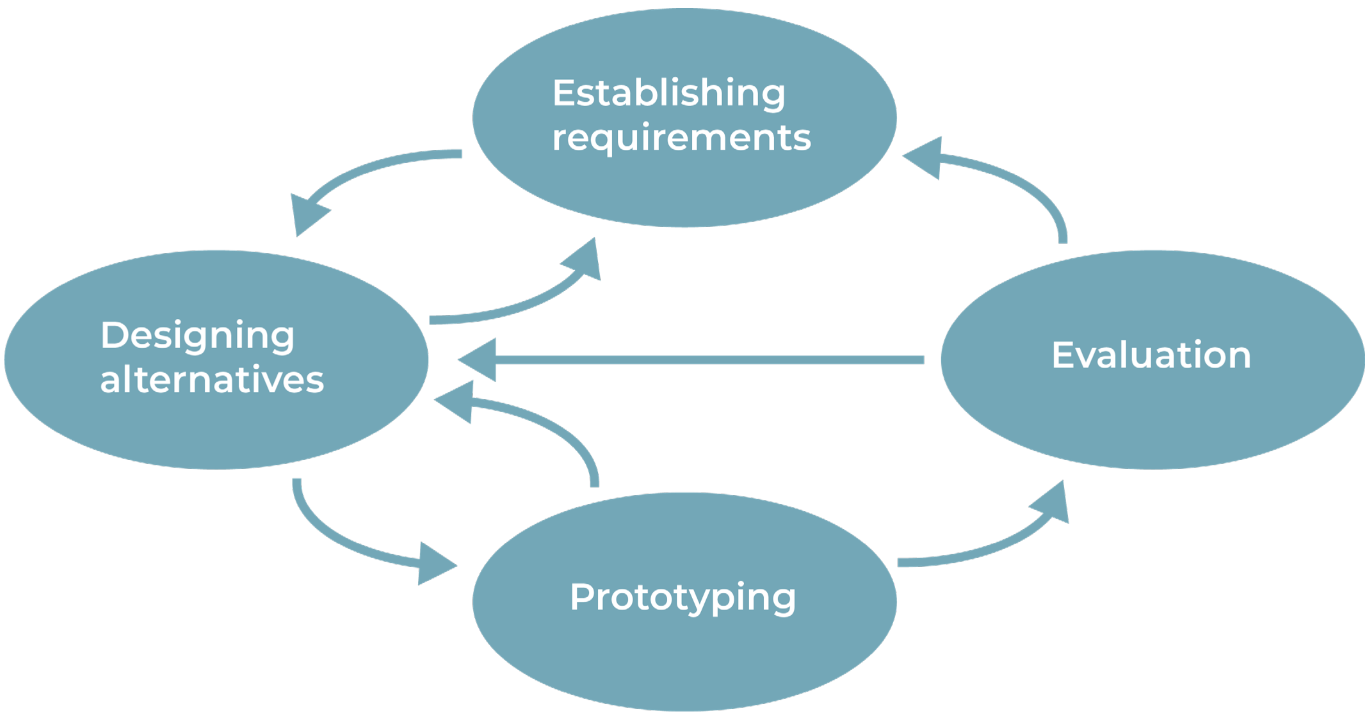


Figure 4.1: Illustration of the Simple Lifecycle model (Preece et al., 2015)

The last and fourth phase in the simple life-cycle model is evaluation. During this step, the prototype is tested and evaluated with the users or stakeholders. After the prototype has been tested, the team may need to return to identify needs, refine requirements, or in some cases go straight to re-designing (Preece et al., 2015). During this process the team can have more than one alternative design, which follows this iterative cycle in parallel with other design alternatives or just a single design may be considered (ibid.). During this phase the product will, through evaluation, emerge from an initial idea to an actual product, ready to be implemented in the use context (ibid.).

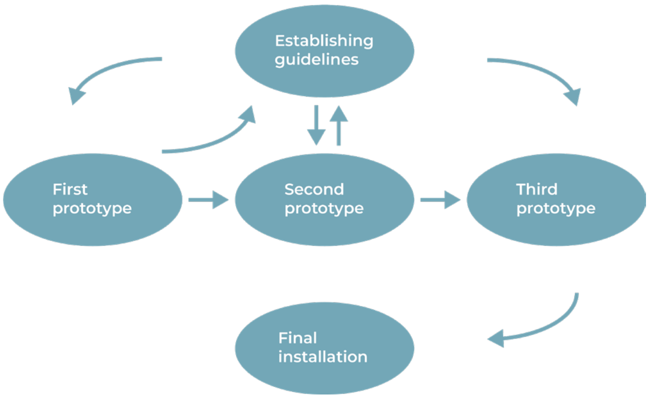


Figure 4.2: Overview of our process

The Simple Lifecycle Model was used in this project to guide the process of the three iterations, and the development of a high fidelity prototype. Every iteration builds upon each other, meaning the results from each iteration were implemented in the next, *see figure 4.2.* It is essential to mention that there were several results from the three tests, and it is only the main key points that will be elaborated. The overall results from each test will be described in detail in the next three chapters.

The design phase, was divided into three iterations, illustrated in *figure 4.2.* In The first prototype, a further development of PinMap was introduced, where a low fidelity prototype was built, this was followed by a test of the prototype, which included various elements the project group wanted to test. One of these elements was, if the map would be viable enough to visualize data understandably. From this, it was discovered, that the majority of the participants found it challenging to understand the feedback provided by the map.

Based on the gained knowledge, the project group decided to make a second prototype to test. The test was conducted to get a deeper understanding of how the users perceived feedback. From the second prototype test, the participants understood the feedback in the form of colored and pulsating light supported by vibrations. From the two tests, knowledge was gained upon what types of feedback methods and interactions the installation should contain.

The third prototype, contained a more narrow scope for the design, this was achieved by exploring and defining the location and target group for the installation. Users were involved in the first phase of the third iteration. The users' thoughts, needs and ideas were an interesting part of this process, to apply a more user centered approach. in The third prototype, the results from the second and first tests were implemented, and design choices were derived from the earlier iterations and the users' response.

The next three chapters, will contain an elaboration of the three mentioned iterations of the design process.

THE FIRST PROTOTYPE

In this chapter, PinMap will be explored in terms of continuing designing the concept, based on the insights from *related work,* chapter 2, and the refinement of the *problem statement,* chapter 3. In Related work, the project group acquired knowledge of weaknesses in related designs and positive aspects the project group found interesting to explore. At this point in the process, exploration is required to determine whether the installation is viable enough to visualize data understandably for the general population of Aalborg. The knowledge and results gained from this prototype were used to develop a second prototype, which will be elaborated in chapter 6*, the second prototype.*

5.1 Concept development of PinMap

The project group wanted to create a prototype, to test the overall concept. To do so, an ideation round began, where different design choices were made. The design choices are made based on the guidelines presented in chapter 1, *Background.*

- **Allow citizens to interpret their everyday environment.**
- **Information and understanding is a key parameter.**
- **Create awareness about pollution**
- **Communicate information that is understandable for the general population of Aalborg**
- **Focus on using spatial visualizations to communicate information to the citizens.**

After selecting PinMap, as described in chapter 1, *Background*, some elements of the concept were still undefined, which encouraged a design phase, before continuing to the prototyping phase.

The concept was based on a physical interactive map, with interchangeable pins. When designing the map, the project group reflected upon, how to make it easy to interpret, but without making it too cluttered as a standard map with roads and city names. To avoid clutter any unnecessary elements were removed from the map and only the main parts were kept, such as the shape of Aalborg and some of the main roads, *see figure 5.1.*

Figure 5.1: Vector illustration of the map

Developing the pins, the project group wanted to create multiple options for the users, so that they could experience more than one type of pollution at the time, at different locations. The project group envisioned it would encourage curiosity and collaboration between users.

Due to icons being a faster way of interpreting meaning compared to plain text (Preece et al., 2015), the concept development included icons on the pins, supported by short descriptions about the parameters.

The project group decided the pins should utilize colors furthermore, it was decided to use bright colors, based on the theory that bright colors draw attention to them (Galitz, 2007). For the colors red was used as a symbol for high concentration and green as a symbol for low concentration (ibid.).

5.1 Making of the prototype

The development of the map for the first prototype was done using Adobe Illustrator, which was printed in an A1 format. The map was glued to a piece of cardboard, where multiple holes were made for the pins, *see figure 5.2.*

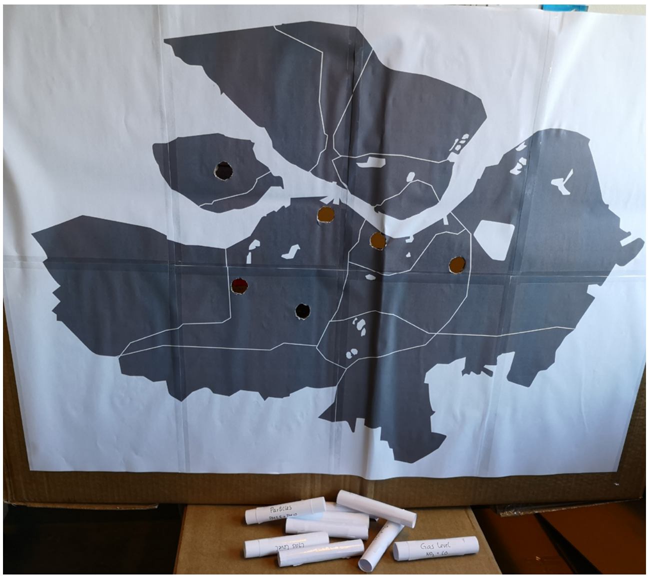


Figure 5.2: The first prototype, here with the map and pins

The pins were created out of paper and tape, and contained their specific parameter on the side. An additional pin was created to test feedback, using a see through plastic tube. One of the paper pins had an icon on the end representing the parameter, another had it on the side, and the last one contained which type of unit the parameter was measured in, *see figure 5.3.*

The project group created different alternatives for the pins, to test which the users perceived the fastest and easiest. The decision surrounding creating three was based on not giving the users too many options, which could lead to confusion (Kucheriavy, 2019).

Figure 5.3: All the paper pins for noise, gas and particles

The colors and light were created using an Arduino and LEDs, which were implemented within the pins.

In addition to the pins, a vibration pattern was created to simulate a heartbeat. The heartbeat intervals differed to indicate high and low concentrations of pollution, high was indicated by a fast beat and low by a slow beat.

The see through pin was developed by using an Arduino and a vibration motor, which were linked with colored LEDs, meant to emphasize each other.

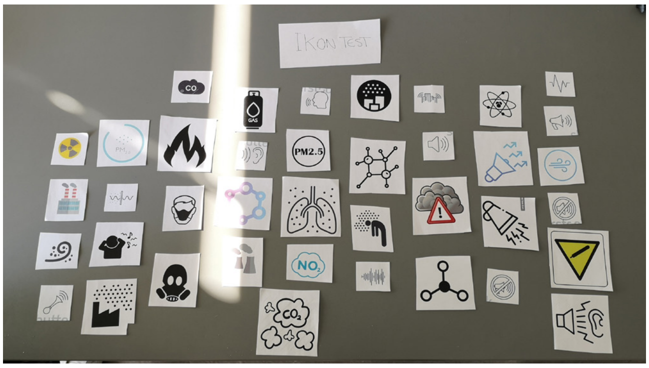


Figure 5.4: All the icons for the selecting game

Creating the specific icons for the test of the prototype, 39 different icons were found, *see figure 5.4*, to symbolize each parameter. The project group considered that the users might not find any of the icons appropriate for the parameter. However, the project group assumed the users would have an opinion on how the icons should look, to support their understanding if none of the selected icons did.

5.3 Test of the first prototype

In this section the first prototype test of PinMap was conducted. The focus of the test was on the overall functionality of the concept, followed by an analysis of the data gathered from the test and at last a presentation of the established requirements.

5.3.1 Interview

Testing the prototype, interviews were used to get insights into the interviewees' thoughts about the current concept.

Interviews can be described as “conversations with a purpose” (Preece et al., 2015 pp. 233). The flexibility of an interview depends on the method used to control the conversation. It is a tool for gathering qualitative data that explores issues of importance to either the design team, stakeholders or the users. Interviews need to be carefully planned to ensure a consistent data gathering process, since it can be very time consuming and to ensure that the gathered data is usable in the following design process. There are four main types of interviews, which are unstructured-, structured-, semi-structured-interview and focus groups (ibid.).
The four types of interviews are all based on the degree of control the facilitator has over the interview.

For this project, semi-structured interviews were used. A semi-structured interview is combining parts from structured and unstructured interviews, where it involves both open and closed ended questions (Preece et al., 2015 pp. 234-234). The interview follows a preplanned script as guidance to ensure the same topics are covered at every interview, which is similar to a structured interview, but the interviewer is encouraged to deviate from the script if they find a line of questioning relevant to investigate. This method can benefit from having a guiding co-facilitator, who ensures the same topics are covered in every interview (ibid.).

To test the first prototype, the project group conducted a series of semi-structured interviews, that covered the different aspects of the prototype. For the test a manuscript was created, *see appendix 3,* the manuscript containing a short introduction about who we are, what the project is about and how the project group would like to proceed. It also contained a selecting game for icons and a test of the map, pins and feedback.
The purpose of the interviews was to evaluate the prototype as a whole, and to get insights into the separate elements.

Participants

Five individuals participated in the first prototype test. Studies show, that the best results come from testing with no more than five participants, and running as many small test as possible (Nielsen Norman Group, 2019). After only one participant, insights of the design increases by a third of all there is to know about the design. With the second participant, there will already be some overlap in their insights. However, the participant will add something new to the data, just not near as much as the first participant. When adding the participants up, the design team will start gaining the same insights over and over again, and after the fifth participant there will barely be any new insights. However, it is recommended to use 15 participants to discover all problems of the design, but the 15 participants can be divided into multiple tests. The overall goal is to make improvements to the design, and not only find the weaknesses (ibid.).

The first prototype test took place at Aalborg University, where two out of the six group members were present. The facilitator made an introduction to the test, where the purpose of the test and each of the parts were described.

5.3.2 Pilot study

A pilot study is a preliminary small-scale study, which researchers conduct to help them troubleshoot and prepare for a larger-scale research study. The pilot study helps the research team refine the initial research questions, and estimate the time and resources it requires to complete the research study (Crossman, 2019).

A pilot test was conducted before the first prototype test. The project group wanted to make sure, that every element of the test worked, so there would not be any complications during the test. During the pilot study, the project group wanted to ensure, that every question asked was formulated in a meaningful way, so the participants could understand the questions. Furthermore, the project group wanted to ensure, the questions the facilitator asked would not give anything away, and thereby cause any biases to the results.

5.3. The four segments of the test

The interview started with a selecting game, which was made by printing various icons that could be interpreted as one of our three parameters, gas, particles and noise, *see figure 5.5.* The icons were then placed in front of the interviewee, which then had to select the icons they felt represented the different parameters in the best way. If they did not find an icon suitable enough, they could draw it or explain how it should have looked to the facilitator.

Figure 5.5: Icons for the selecting game

Continuing the interview, the project group was interested in testing the map of Aalborg. In this part of the interview, the focus was on clarity, to explore if the participants could see what the map represented and how they were supposed to interact with the map, *see figure 5.6.*

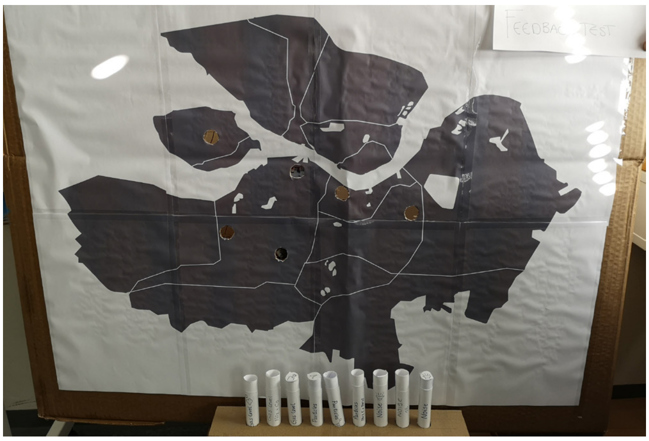


Figure 5.6: The prototype containing map, holes and pins

Testing the pins, open-ended questions were created concerning physical appearance. These questions were to answer the hypothesis about, whether icons are easier and faster to interpret than text. The participants were to select the pin they thought represented Particles, Gas or Noise in the best way, *see figure 5.7.*

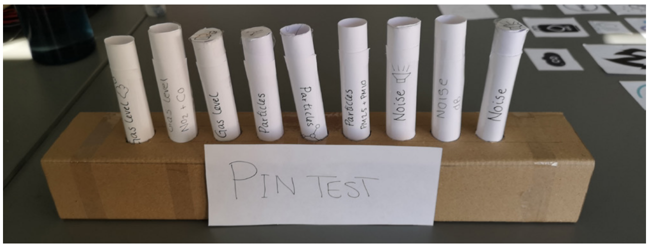


Figure 5.7: The pins for particles, gas and noise

The project group tested the feedback of the prototype with map, pins and vibration patterns. In this test the participants were encouraged to interact with the prototype, and try to explain what they thought the feedback represented. They were asked to place a pin in one of the holes in the map and the pin would vibrate and a red or green pulsing color would occur, depending on the level of pollution. The project group asked the participants, what they thought it might mean and the goal was to see if they understood the feedback the map provided.

Figure 5.8: Debriefing session after the pilot test

After the interview and tests, there was a short debriefing session where the users were asked how they experienced the test, and if they had any questions, *see figure 5.8.* The debriefing session also included a full description of the project and was implemented as a natural ending on the conversation.

5.4 Analysis of the prototype test

After the prototype test, an analysis of the gathered data was conducted. To analyze the data, the project group used an affinity diagram, which resulted in an overview, and allowed grouping common opinions together, *see figure 5.9.*

Figure 5.9: Affinity diagram of results

On the X-axis the four different tests were presented; Pin test, Feedback test, Icon selection, Map test and Debriefing. Beneath each test, notes from each test subject were clustered together based on preferences from the results.

The results showed, that four out of five participants preferred an icon on the end of the pin. Furthermore, the majority of the participants also wanted text on the side of the pin. A participant stated:

"I was a little confused about what the icon meant, but when I read the text on the side, it became clear to me, what the pin represented."

The icon test showed, that the participants preferred particles visualized with dots, whereas the gas icon had to be visualized with clouds. Lastly, the noise icon had to be visualized with a speaker, *see figure 5.10.*

Figure 5.10: The selected icons for the three parameters

From the feedback test, four out of five participants expressed, that the pulsing red color of the pin presented a lot of pollution, whereas two of them thought they had done something wrong. The majority of the participants expressed that the pulsing green color, represented the opposite of the red color, meaning it was more environmental friendly.

The map test resulted in two of the participants were aware of the map representing Aalborg, whereas it was not clear to three of the participants. It was clear to them, that it was a map, but they were unsure of what the map represented. A participant stated:

"I know it is a map, but I am not sure, what the map represents."

The majority of the participants, knew that they should insert the pin in the map. However, a few of the participants were not sure, why they should insert the pins. One participant thought he should insert his finger, which was due to the participant not being able to see the pins.

In the debriefing session, the majority expressed, it would be a good idea to visualize more clear that it was a map of Aalborg. Another expressed, the use of magnets would be a good idea, so that one could insert the pins all over the map. Overall, the feedback from the map needed to be more clear and the interaction between the user and the map had to be more obvious. The majority of the participants were confused about the context of use and unclear about the purpose.

With the analyzes in mind, requirements for the installation were made. These requirements were based on the results of the gathered data from the prototype test.

Product requirements

- **The pins must include relevant icons and descriptive indicators**
- **The map must be detailed enough, so users can associate the map with Aalborg**
- **There must an easy and understandable interaction with the map**
- **It must be easy to understand and interpret the feedback.**

THE SECOND PROTOTYPE

In the previous chapter, the project group acquired knowledge about weaknesses and strengths with the installation. The main weakness was that the participants did not understand the feedback and the overall context the map provided. With this in mind, another prototype was developed. The goal of this prototype was to test different feedback methods, which was based on the results from the first prototype test. It was important that the users of the product understood the feedback, as this was the main priority from the guidelines presented in chapter 1, *Background.*

As mentioned in chapter 4, *Method*, the project group used the *Simple Lifecycle Model for Interaction design,* and at this point in the process, we are testing and exploring design alternatives in the form of feedback and interaction methods. This chapter will not contain an exploration of other results from the first prototype, except for feedback and interaction. The participants gave the project group clear insights about how the pin, map, and icon could function in the installation, however, the feedback of the first prototype was unclear to the participants, and will, therefore, be the main focus of this chapter.

The other results from the first test, will be explored in chapter 7, *the third prototype*, where a combination of the gathered data will be used as a tool to make the design choices for the installation.

6.1 Feedback test

The purpose of the feedback test was to explore how users best perceived the data visualized through the map, and if the users could spot whether low or high concentrations of particles, noise or gas were visualized.

From our first prototype test, described in chapter 5, only a cylinder-shaped pin was tested. However, in this test, the project group wished to test multiple ways of interacting with the map and gain feedback, to get insights about what the users preferred.

Several tangible objects were considered for the interaction with the map. However, the project group decided to include a pin, a magnet, and a button. The project group wanted to test the pin compared to other tangible objects, and due to the research made in *Related Work*, chapter 2, and the wish from a participant in *the first prototype test*, chapter 5, magnets seemed like a good alternative. Buttons were considered, due to their simple form and implementation.

The feedback test was split into five different parts, each containing different feedback methods, *see figure 6.1.* To see the full structure of the feedback test, *see appendix 4*, Structure of the feedback test.

The test contained five parts, which can be *seen in figure 6.1.*

1. part
- Pin
- Magnet
- Button

2. part
- Pulsating light
- Colored light
- Increasing light
- Expanding light

3. part
- Heartbeat vibration
- Pulsating vibration
- Increasingvibration

4. part
- Animation

5. part
- Sound

Figure 6.1: Feedback tests five parts

6.1.1 The making of the prototype

The second prototype contained five individual parts, where each represented the five different feedback methods, that the project group wanted to test.

In the first part of the test, a cardboard box was used, where a hole was engraved. The hole was made as a point to insert the pin. Furthermore, a magnet was placed behind the cardboard. The magnet was implemented, so another magnet could be placed on the front of the cardboard box. Lastly, a button was placed on the cardboard for more tactile feedback, *see figure 6.2.* The project group was interested in exploring whether the different input devices, would change or optimize the user experience in any way.

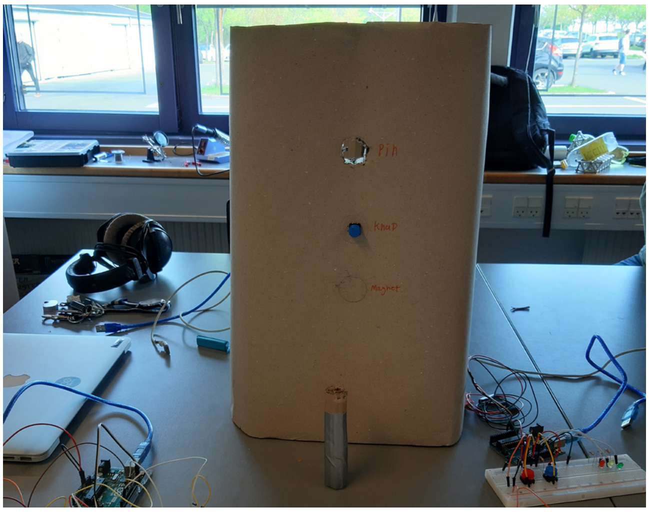


Figure 6.2: Feedback prototype, containing a button, magnet, and a hole for a pin

The second part of the test included three different types of light, these being pulsating light, colored light, increasing light and expanding light. The pulsating light was created to include three variations of pulse, which differed in their speed of the puls. The colored light included three colors, these being red, yellow, and green (Galitz, 2007). For the increasing light, a shape was used that was filled with three different volumes - one with an approximate 10 %, one with 40 % and the last with 80 %. The expanding light was build with three rings, where the light could spread to, *see figure 6.3.*

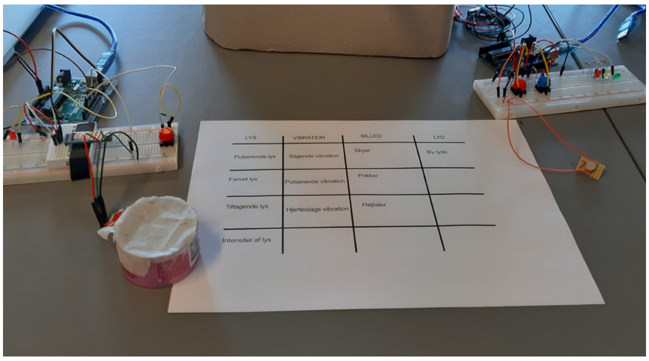


Figure 6.3: The light and vibration test

For the third part, three different vibration patterns were created, *see figure 6.4.* These patterns included heartbeat, pulsating, and increasing, which all were created with three different intensities.

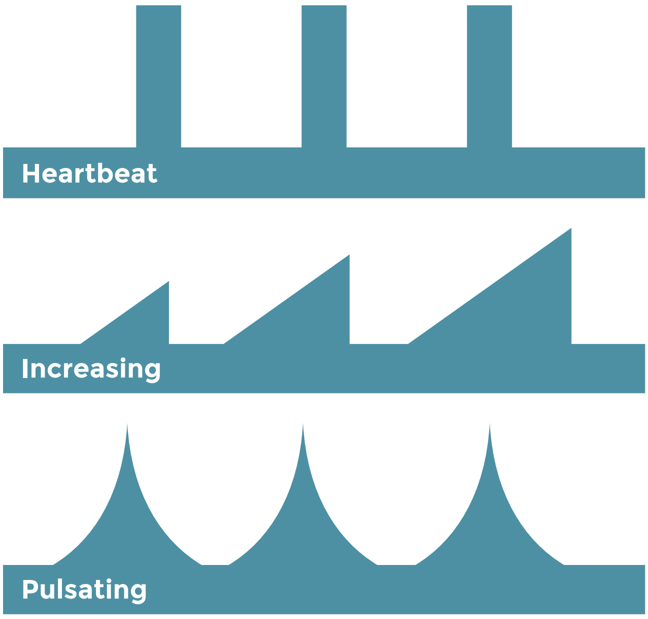


Figure 6.4: Visualization of the different vibration patterns

Figure 6.5: Animations used in the animation prototype

In the fourth part of the test, the project group decided to use animations. The animation was created by making three illustrations in Adobe Illustrator. The three illustrations contained different facial expressions in combination with illustrations of different levels of pollution, *see figure 6.5.* The three illustrations should visualize different levels of intensities in the three parameters, *noise, gas, and particles.* The Illustrations were printed and each placed on a cardboard disc, where the test facilitator could slide between the three intensities, *see figure 6.6.*

Figure 6.6: Animation prototype including different illustrations

In the fifth part of the test, three different sound samples were downloaded. The first sound was from a park with birds and wind flowing through the trees. The second was from a pedestrian street, with people walking and talking and a few cars driving by. The third sound was from a big city with a lot of traffic and cars honking. These three sound samples were played for the participants during the test in random order.

6.1.2 Participants and scenarios

Six participated in the feedback test. The test took place at Aalborg University, where three out of the six group members were present. The facilitator made an introduction to the test, where the purpose of the exploration and each part were described.

The test was structured as a semi-structured interview, where the project group constructed a script to make sure every participant was asked the same questions. A scenario was presented to the participants at the beginning of the test to communicate the experiences of interacting with the map. This scenario was made to make it easier for the participants to imagine the situation before testing the different feedback methods.

“You go for a walk in the library, and you spot a map that shows an overview of Aalborg. You get closer and see that you can interact with the map. The map visualizes pollution in the city, and you become interested in knowing how much pollution there is in your area. You want to see how much gas is in your area."

"You want to interact with this map, and you have three options for how it goes; a magnet, a button, and a pin. Try to use them and tell us what you think about."

Depending on what interaction method the participant chooses, the scenario changes. In the second part of the test, the facilitator made a follow-up scenario:

*"You **place/push** a **pin/magnet/button** on the card and you see the pollution in this area."*

The facilitator then asked the participant what they thought represented a low level of pollution and what represented a high level of pollution. These two questions repeated in each part of the feedback test.

Pilot study

A pilot study was conducted, with the same form as described in chapter 5, *the first prototype.*
The results from the pilot study showed, that the increasing light needed to be changed, due to the light barely differentiating in intensity, which made the task difficult for the users. In addition, parts of the script needed to be rearranged in a different order, to create a better flow in the test, but also to test if the participants could recognize the difference between the intensities instead of going from low to high.

The five parts of the test

In the first part of the feedback test, we tested the interaction with the map. The test was created using a pin, magnet, and button, as described in section 6.1 *Feedback test.* The purpose of the test was to get insight into the users' preferences and to explore which input devices had the most significant potential in the interaction between the user and the map.

The second part of the test focused on light, which is elaborated in section 6.1 Feedback test, the participant was asked to identify which of the three variations were high, medium and low levels of pollution.

Vibrations were tested in the third part. As with the lights, the participant was asked to rate the intensities of each type between low, medium, and high.

In the fourth part of the test, the participant was asked to identify which of the three pictures on the discs, symbolized low, medium ,and high pollution.

In the fifth test ,three different sounds were tested. The participants had to identify what level of pollution matched with the different sounds and whether it symbolized *noise, gas, or particle* pollution.

6.1.3 Analysis of the feedback test

The feedback test resulted in knowledge about how the participants perceived the different feedback methods and what feedback methods were the most efficient for visualizing the data from the CityProbe.
For analyzing the qualitative data, which was collected within the test, the project group used an Affinity diagram. The Affinity diagram was used to get an overview of the unstructured data, *see figure 6.7.*

The affinity diagram was structured with a focus on the participants' understanding of the data. The participants' understanding of the data was classified into three divisions; a common understanding of the data, an average understanding of the data and does not understand the data.

Figure 6.7: Affinity diagram created from the feedback test

The data resulted in a list of feedback methods that the participants had the best understanding of.

- **The magnet was the preferred input device.**
- **Color and the pulsating light**
- **Heartbeat vibration as a support, but not on its own**
- **Animation**
- **The sound used as support mainly for animation**

The majority of the participants expressed an unclear understanding of the sounds if they were set to visualize the three parameters, *noise, gas, and particles* on their own. All of the participants expressed that sound in cooperation with animation would be the best way of using sound in the context of the project.

To avoid the implementation of displays in the installation, the project group chose to focus on light and vibration as the feedback methods. This resulted in the project group not proceeding in using animation to visualize pollution. Furthermore, the sound was removed, which was based on the feedback from the participants, about the sound not being able to stand alone.
The feedback from the light test argued that the speed and color of pulsating light were the best indicators for high and low levels of pollution, green and slow being the lowest level and red and fast being the highest level.

All levels of vibration were hard to differentiate, which resulted in the participants only being able to sense the difference in interval between the vibrations, and therefore found the heartbeat vibration the easiest to interpret.

Update of requirements

With the analysis in mind, new requirements were made. These requirements were based on the results of the data from the feedback test. The project group decided to assemble feedback requirements and product requirements.

Product requirements

- **The pins must have relevant icons and descriptive indicators**
- **The map must be in detail, so that users can associate the map with Aalborg**
- **There must include an easy and understandable interaction with the map**
- **It must be easier to see/understand and interpret the feedback.**

Feedback requirements

- The user must be able to attach the pin with a magnet
- The feedback must be visualized in colors and pulsating light
- Heartbeat vibration must be used in the pin

THE THIRD PROTOTYPE

In the previous chapter, knowledge was aquired about feedback methods for the installation. The gathered results will be implemented in different design choices, and the design choices were made based on the requirements from the previous chapters. Furthermore, it contains a description of how a high fidelity prototype was developed and evaluated. The target group will be further narrowed down, and a specific location for the installation was selected.

Before continuing the development, the project group wanted to explore the target group. Doing this will narrow the scope of the project and make the continued development less challenging. Furthermore, the project group is interested in knowing the user's thoughts on the initial problem and what they currently do to minimize pollution. The purpose of this was getting inspiration for some final design choices. Moreover, the insights into users thoughts and ideas of the installation, would support the project group in designing an installation with a user-centered approach.

To define the target group, the project group selected a location. This was followed by a data gathering process including observations and interviews. The observations were meant to explore the flow of visitors and to assume who the visitors are.

7.1 Determining the audience

Semi-structured interviews and observations were used to determine the audience. Through these methods, the project group created personas, which resulted in user requirements for the installation.

Defining the location

The project group researched various locations that seemed appropriate for reaching the general public of Aalborg. It was important for the project that the location was open to the general population of Aalborg. The locations considered in Aalborg were, Kennedy Arkaden, Nordkraft, Utzon Center, Aalborg main library and the art museum Kunsten

After visiting a few locations in Aalborg, the project group decided upon the location Aalborg library due to the majority of the people were within the user segment for this project. The project group discovered an exhibition area at the location, which was easily accessible to the general population of Aalborg. Unlike The Utzon center and art museum Kunsten where the exhibition areas cost money.

7.1.1 Target group

After selecting the location, the target group was defined. This was done by conducting observations and later interviews at the library. The observations and interviews were later combined to create personas that defined the specific target groups.

Observation

The project group made observations at Aalborg library, the purpose of the observations was to acquire knowledge about the citizens visiting the facility, and furthermore gaining an understanding of the environment. Three out of the six group members who made the observation was located in an exhibition area right next to the entry. It was important that the group members had a clear view of the visitors of Aalborg library. Two of the group members walked around and observed, how the visitors spend their time at the library, whereas another drew the flow of the visitors where they went and the area they spent the most time in at Aalborg, *see figure 7.1*. After the observation, it was possible to identify where the users often went and where there was a constant natural flow. As seen in the figure, there was especially a large flow from the study-area and to the water dispenser in the exhibition area. In the exhibition area itself visitors rarely looked around, visitors mostly walked through the area.

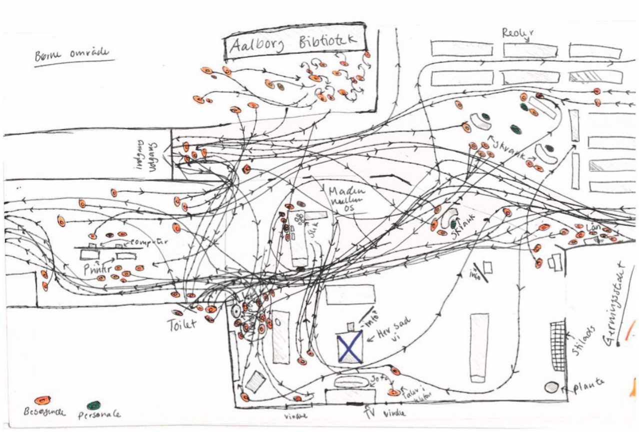


Figure 7.1: Observed movement pattern at Aalborg Library

The placement of the installation needed to be placed, where it would be visible for the visitors of the library and also where there was a high flow of people. The place near the water dispenser became the place, where the installation was to be placed. There is a high flow of people and it is to the right of the entry, so the visitors have a clear view, *see figure 7.1.*

It can be very challenging for people to describe what they do, and sometimes, they are not completely aware of their actions (Preece et al., 2015 pp. 252-253). There are two types of settings to conduct observations within, these being in the field or in a controlled environment. Observation in the field involves users being observed while they perform their daily tasks in a natural setting, while observation in a controlled environment involves performing specific tasks within an artificial environment, such as a usability lab. To acquire the information, it can, therefore, be necessary to conduct observations in the field. Observation is a useful data-gathering tool allowing the design team to gain insight into the user's environment. The technique can be used throughout the whole design process by giving valuable insights into the user's needs and requirements (ibid.). When observing users in the field, the events can easily be very complex and it can be a challenge to observe the users actions. Furthermore, it can be difficult to get everything down on paper, and the chance of missing something is possible (ibid.).

From the results of the observations on the Library, the project group drew some assumptions. These assumptions being that the people entering the Library all had a specific goal and that they primarily were in the age group between 20 and 60.

The project group wanted to confirm their assumptions from the observation, but also get an expanded understanding and knowledge about the users. This was done by conducting various interviews, which combined with the observations, was shaped into personas for the specific target group.

Interview

Interviews were conducted at Aalborg Library, to get insights about the user's interest and understanding of their standpoints on climate changes, pollution and technical skills. *See appendix 5, Interview structure at the library*, to see the full interview. Seven users were interviewed in the age group 20

- 30 and three in the age group 45 - 60. The questions that were asked during the interview focused on the user's age, occupation and technological skills, how they spend their time at the library, their thoughts on pollution, what they do to minimize pollution, and if they would be interested to know more about pollution.

The majority of the people in the age group 20 - 30 are concerned about pollution, and had some idea of how to minimize it, an interviewee expressed:

"I think about pollution a lot. We have to think about it. I really don't know what to do to minimize it, but it would be interesting to know how to and more about pollution."

The interviewees associated pollution with everyday things, like cars and buses which are a part of their daily life. The participants knew, that it would be better for the environment, if they would take the bicycles as a means of transportation, however, some expressed that they had no other choice than to take the car, but if it were possible, they would take the bus or bicycle. An interviewee expressed some interest in seeing different levels of pollution in specific locations around Aalborg:

"It would be cool if you could see specific locations with different levels of pollution in Aalborg."

The interviewees in the age group of 45 - 50 were more aware of the consequences following pollution. One mentioned that they were building their own house out of wood, because she assumed it was better for the environment. Another interviewee stated, that she drives an eco-friendly car. The interesting aspect of the interviews was that they were all aware of pollution and tried to minimize it in their own way. An individual said:

"Air pollution scares me because I am afraid of what I am inhaling."

An Interviewee mentioned that she thought a good idea to minimize the pollution would be to sort ones garbage and use carpooling as a means of transportation. In addition, a participant mentioned that she removed the woodburning stove from her house, and she was aware that stoves are some of the highest sources of air pollution.

Most of the interviewees had an idea of what to do to minimize pollution in the environment, but they did not know what effect it would have on the environment if they would take the bicycle instead of the car.

Personas

With the data from the interviews and observations, two personas were constructed. These personas represent the two age groups, which were interviewed in the previous section. Due to the differences between the two age groups, the project group decided to create a primary- and a secondary target group. The primary target group was the age group of 25-30, because that was the largest group of interviewees and also the group of people that was observed to have the most significant presence at the location. The secondary target group was more aware of the problem than the primary target group. They knew more about what could be done to minimize pollution, where our primary target group had limited knowledge on the topic.

A persona is a descriptive model of a user, based on a qualitative study, which can help gain insight into user's behaviors, wishes or frustrations (Cooper et al. 2014 pp. 75-76). Personas are based on user archetypes, which can be a helpful tool to communicate the motives in the design team and thereby help justifying design choices.

When creating personas, it is important to be cautious about issues, that might occur (Cooper et al. 2014, pp. 82). There can be many different individual characteristics, and it can, therefore, be difficult to accommodate every characteristic of the individuals. With that being said, it is important to look for similar patterns among the individuals, such as behavior or motives (ibid.). Although it can be difficult to find a line between making the personas either too general or too specific. By making the persona too general, empirical data of the differences among the user groups might be lost. With this in mind, it is therefore essential to consider how many personas are needed to explain the behavior, motives or frustrations of the target group (ibid.). When making personas, it is also important to avoid creating elastic users and self-referential design, where the design team tries to affect users to fit their own goals and visions for the project. (Cooper et al. 2014, pp. 79-80)

Our personas

The two personas were made to help communicate the behavior, goals and frustrations of our target group. The project group found it necessary to create a primary and a secondary persona to fully cover the variations of motives and needs derived from the data gathered. After compiling similar and interrelated data, we ended up with the personas, Maria and Henrik, *see page 49 and 50.*

Maria Knudsen

25 years old

FACTS

Employment: Student
Family: Boyfriend and no children
Technological competence: over average, 7
(from 1-10)

BIOGRAPHY

Maria is an outgoing woman who is very focused on her education. She lives in the city center of Aalborg with her boyfriend, Søren. She is interested in the environment, but lacks the knowledge of how she can contribute to improve it. She uses the library to study, and therefore wants peace to concentrate. Maria does not borrow books at the library, but only uses it to study and meet with her study group.

BEHAVIOUR IN THE LIBRARY

Sitting in the research room or in the ”quiet zone” to study. She does not use the libraries other facilities but only uses it to study. If she needs a break from reading, she then goes for a walk outside with her group.

She gets frustrated if there is a lot of noise in the library and if the piano is played.

THOUGHTS ON POLLUTION

Since it has become a major topic of discussion in society, Maria has begun to think about pollution in urban life. Maria has an idea of what to do to reduce pollution, but she lacks more specific knowledge. For instance, Maria doesn't know how bad the pollution is in her area, or in general around the world. Maria has thought of taking the bike instead of the car as she thinks it will help the reduction.

WISHES

Maria thinks it would be interesting to get knowledge about pollution in urban life. Especially if one can see pollution in certain areas. She wants to know what she can do to reduce pollution.

Henrik Møller

54 years old

FACTS

Employment: High school teacher
Family: Married and has 2 adult children
Technological competence: Medium, about 5 (1-10)

BIOGRAPHY

Henrik lives in Vejgaard with his wife Johanne where they have a quiet everyday life away from the centrum of Aalborg. Henrik is a relaxed person who is excited about teaching and likes his job. Henrik and Johanne have two children who don't live at home anymore, and therefore Henrik and his wife spends a lot of time arranging the garden, because they like to be out in the fresh air.

BEHAVIOUR IN THE LIBRARY

Henrik is very focused on what he is looking for. He does not stay too long at the library. Henry gets frustrated when he can't find his book. It makes him easily irritated. He wants the visit to be fast without too much idle time.

THE USE OF THE LIBRARY

Henrik does not use the library as often, but visits it once every two months. He uses the library to borrow books for the holidays or professional literature in relation to his profession. He is driven by learning and would like to explore opportunities and therefore find it exciting to explore the exhibitions in the library to learn something new.

THOUGHTS ON POLLUTION

Henrik is thinking about pollution, and he is very aware of what he can do to help the environment. He uses the car to and from work every day, but he is aware of the importance it has for the environment.

WISHES

He thinks it might be interesting to know more about pollution in urban life. It is important for Henrik to hand over a healthy environment to the next generations.

7.1.2 User requirements

After developing the personas, it was possible for the project group to establish user requirements for the installation. These were anchored with the personas and guidelines in mind. These user requirements should ensure the users' needs and wishes were met when further developing of the design.

- **Make it possible to choose a focus point on the map**
- **Awake the interest to interact with it.**
- **Provide clear feedback about pollution in Aalborg**
- **Provide information on how the users can minimize the pollution themselves**
- **The interaction with the installation must be exciting**
- **Create an experience**

7.2 Design choices

In the following section, design choices will be explored and described based on the results from the previous tests, the user research, and the guidelines described in Chapter 1, *Background.*

7.2.1 The map

The map has so far been the outline of Aalborg municipality. The project group chose to change the shape of the map to focus on central Aalborg, where most of the CityProbes were active. During the development of the components for the second prototype, the project group realized that the map was too large in scale compared to how close the probes were placed. By focusing on a smaller area, the size was retained, which enabled us to make the map more detailed. On *figure 7.2, t*he area of focus is narrowed down with strings, where the pins represent the CityProbes in Aalborg.

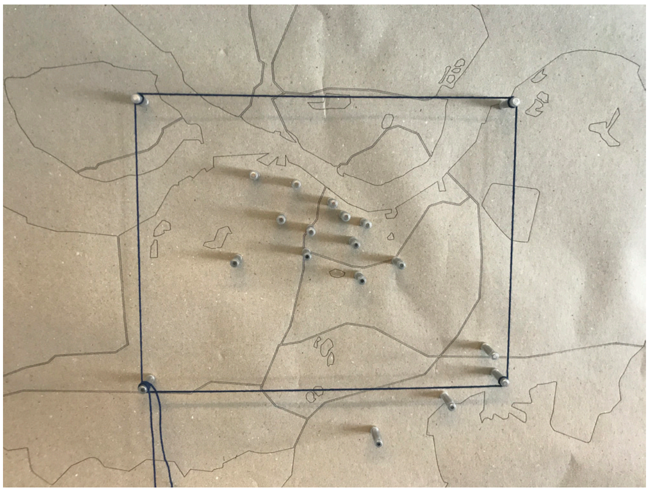


Figure 7.2: New focus area of the PinMap

In addition to this, the participants from the first prototype test expressed that they were not sure of what the map represented, but they could see that it was a map. To avoid the confusion, we chose the write Aalborg above the map to make it clear that the area on the map was Aalborg. New main roads were added, to give the map more shape, so city areas were recognizable. For the same reason, city attractions from Aalborg should be attached to the map to make it easier to locate different city areas.

Size and ergonomics considerations

To determine the scale of the prototype to make it feel comfortable and work within the standards of human ergonomics. An article described that in Denmark, the average height of a grown-up woman is 167.2 cm, and the average height of a man is 181.4 cm (Elifesciences.org, 2016). The cardboard mockup of the map was created in a 1:20 scale. Human models were made in the average height of a man and woman, *see figure 7.3.*

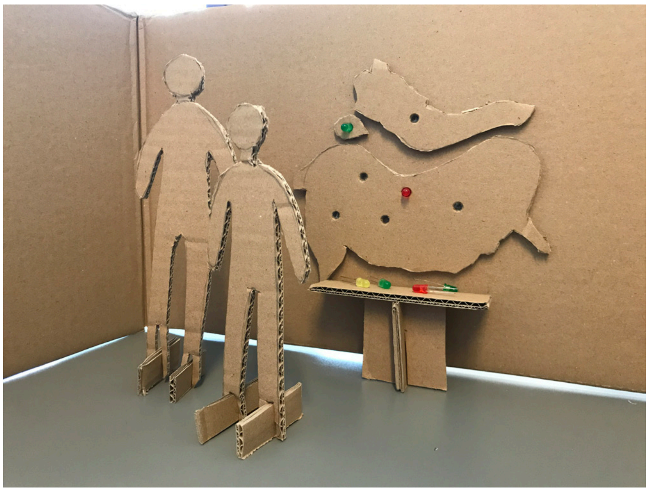


Figure 7.3: Cardboard mockup in a 1:20 scale

The mockup was made with the focus of understanding the scale of the human and the ratio between the height of the visitors of the library and the size of the map. Pictures taken from the users perspective enabled the project group to consider the appropriate scale, *see figure 7.4*. The model was a beneficial prototyping tool to facilitate dialog in the project group regarding building the full-scale prototype.

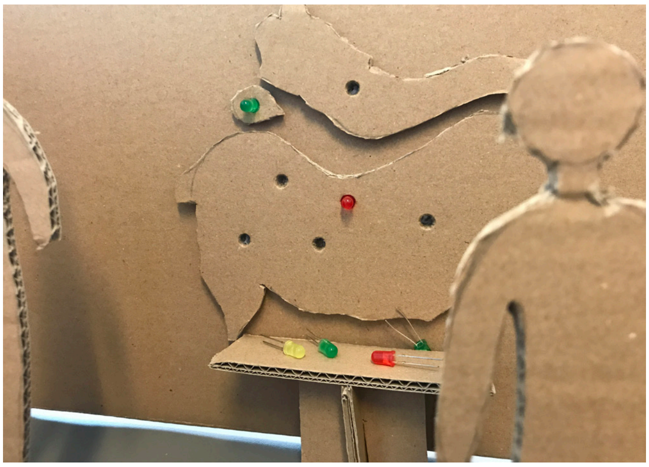


Figure 7.4: User perspective in a mockup

When interacting with the installation should be within a comfortable arms reach. The average arm length for a grown-up man is 72,4 cm and for a grown-up woman 65,7 cm (Dreyfuss, 1966). When standing in the front of the installation, the size of it should be within reach of 131,4 cm to make it possible for both a man and a woman to reach every corner of the map.

To ensure the installation was within the vision of discrimination of colors, The Measure Of Man by Henry Dreyfuss was explored. Within 60 degrees from the human eye, is it possible to discriminate colors (Dreyfuss, 1966). At a distance of one meter to the installation, the perception of color and light will be clear, and the discrimination will be within 120cm.

When placing the installation on a wall in the library, it would be beneficial to place it in a height that is comfortable to look at for a grown up. Therefore, the project group wanted to explore how the vision is affected at a distance. It was found that at a distance between 1.2 meters and 2.1 meters, it will be possible to see the size of a human's upper body (Hall, E. 1966). With the size and the height in mind, the installation is placed on the wall.

Based on all these considerations and measurements, it was determined that a comfortable size within the ergonomic constraints for the map would be 84cm in width and 59cm in height. It would be hung up at a wall in the same height as a human's upper body to ensure a comfortable interaction.

7.2.2 The pin

In the analysis from the feedback test, 4 out of 6 participants preferred to interact with the magnetic pin as the primary input device on the map, instead of inserting a pin or pressing a button. One of the participants expressed at the feedback test:

"The best one is the magnet, that is cool and a fun way of doing it."

Based on this data, the project group decided to remove the predefined holes from the map, since the participants preferred to interact with a magnet. From the interview in section 7.1, *Determining the audience*, an interviewee expressed, that it would be interesting to see the level of pollution at specific locations around in Aalborg. With the magnet, users would be able to select any focus point on the map, and thereby see pollution at a specific location.
The magnetic pin design drew inspiration from a map pin, with a round sphere on the top, which would make it easier to grab and hold when interacting with the map.

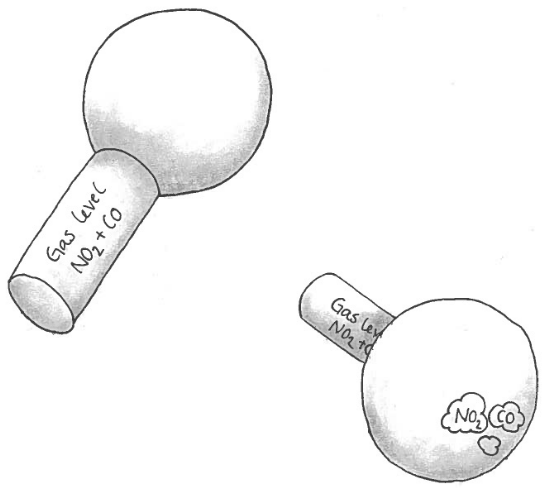


Figure 7.5: Magnetic pins with icons and text association

Each pin represents a parameter, which is *noise, gas, and particles.*
From the first prototype test, we found that the participants preferred to have meaningful icons placed on top of the sphere of the pin, accompanied by a short description on the side of the cylinder, *see figure 7.5.* From the same test we also found which icons the users associated with each parameter.

Size and ergonomic considerations

We assumed that the sphere of the pin was the most natural part to grab when interacting with the pin. It was essential to create the pin in an appropriate size that was comfortable and natural to grab and hold on to with no struggle. The members of the project group all tried to hold different sizes spheres to see which size will feel most comfortable. With these considerations, the pin was made slightly smaller than what was possible to hold for all the group members, to ensure that the sphere of the pin would not shade for the light on the map, *see figure 7.6.*
The magnetic pin is referred to as the pin from here on.

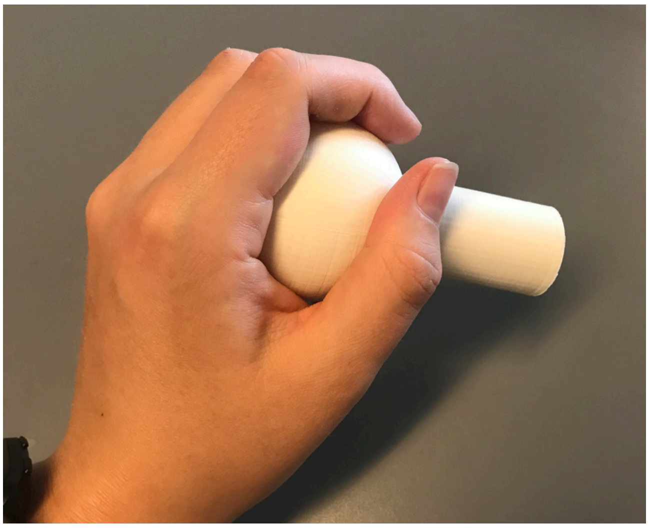


Figure 7.6: Ergonomic consideration of the pin

7.2.3 The feedback

Participants from the feedback test responded well to colored and pulsing light. Here the participants found it easy to associate green color as an area with low intensity of pollution, yellow light as an area of the medium intensity of pollution and red light as an area of high intensity of pollution.

The pulsing light also gave a good indication on whether the area had high levels of pollution or low pollution, based on the tempo of the pulsating light.

One participant mentioned fast pulsing light reminded them of a warning which they thought was the right way of visualizing that the area had high levels of pollution.

As described in chapter 1, section 5 *User experience*, people have a higher memorization rate when they can associate colors with something known (Kucheriavy, 2019). In our installation, colored lights are used to visualize the levels of pollution. The colors should conform to rational expectations, and the meaning of the colors should already exist in a person's world (Galitz, 2007, pp. 635). Red is commonly associated with stop and danger, where yellow commonly associated with caution, and green with go, OK, and safety (ibid.).

It was necessary for the project to keep a consistent design and limit the amount and numbers of colors to keep the design simple, in order for the users to interpret the design as clearly as possible. (Shneiderman & Plaisant, 2010, p.487)

Another type of feedback participants clearly understood was the heartbeat vibration. A participant at the feedback test said:

"When the heart beats fast, it represents a high level of pollution, and when it beats slow, it represents low-level pollution."

Participant number 3 mentioned that light and vibration could work well together. At the feedback test, a participant said:

"It would be great to put the light around the pins in the area of where you put it."

With these findings, the project group chose to have the effect of pulsating colored lights coming from inside the map around the pin, wherever it would be placed on the map. The pin should also be able to sense when it is being placed on the map and vibrate in a heartbeat pattern to communicate pollution levels.

7.2.4 Data modifiers

Through the interviews at the library, the interviewees also stated this would something they would like to see as described in section 7.1 Determining the audience. The majority of the interviewees mentioned everyday things, such as public transportation and bicycles, when talking about minimizing pollution. Indicating that they would be interested in seeing how this would affect pollution. Including this aspect into the design vision, could be an effective way to make users put pollution into perspective.

The project group chose to add four modifiers to envision the reality, that would make it possible for the user to see the real CityProbe data manipulated. Furthermore, the project group would add an option to change the current time of day, which was an idea pitched by Montem so the user would be able to see how the data changes throughout the day. The four modifiers are:

- **Double the amount of cars in Aalborg**
- **Remove all cars from Aalborg**
- **Remove all wood burning stoves in Aalborg**
- **Change the time during the day**

The purpose of these modifications is to give the users an insight into how much of an effect it would have on Aalborg if. An example is the number of cars was doubled or if all cars were removed from Aalborg.

As stated in chapter 1, section 5 *User experience*, it is essential to consider how much information is available for the users and how many options they have. Andrew Kucheriavy mentioned that four seems to be the number of items users can remember. Based on this, the project group decided to implement the four modifiers of City Probe data.

As described in chapter 1, section 5 *User experience*, it is vital that the design should fit the needs and interests of the personas. It is the project groups goal to design an installation, which stimulates the users' interest. Through the interview, we found that the interviewees had an interest in knowing how to minimize pollution in the environment. The project group then looked into how to design an installation, which tries to pique the interest of the users. With the four modifiers in the design, we are providing the users with insight into the effects cars and woodburning stoves could have on the environment, and from that, they can make up their own opinion from what they have seen.

7.3 Interaction with the installation

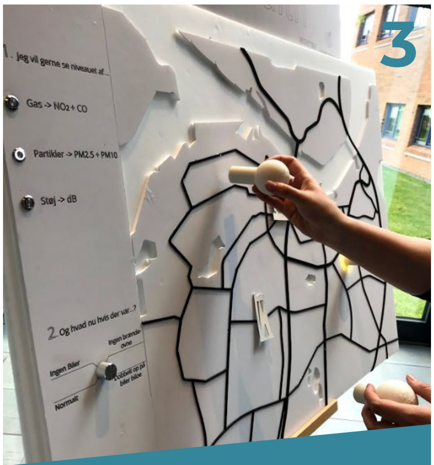
In this section a thorough walkthrough of the interaction with the installation will be given, followed by an estimated time the two personas would interact with the installation as well as where it should be placed according to our observations. At the end of the chapter, the conceptual ideas of a full exhibition will be explored.

When users walk up to the installation, they will see a map over Aalborg where three pins, representing *Noise, Gas, and Particles* are in front of the map. When the users place a pin on the map, the pin will stick to the map with a magnetic force and the users can then place the pin at different locations on the map. When the pin is placed at a location, lights will start pulsating around the pin. If it is a location with a high level of pollution, then a circle around the pin will start pulsating with a red color. The users will notice, when they place a pin at another location, that the circle will start pulsating in green, red, or yellow depending on the level of pollution. On the side of the map, the users can interact with a rotating knob, where they either can choose double the amount of cars in Aalborg, remove all cars, remove all woodburning stoves or change the time of the day. If the users decide to remove all cars, then they will see how the circle around the pin starts changing color according to the pollution level with the modifier applied. The to see a storyboard of the interaction, *see page 56.*

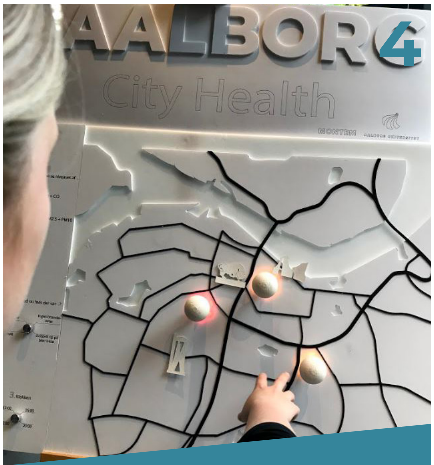
Story-board

A visitor is out for a walk in the library and walks by the exhibition area where she sees an installation that catches her eye.

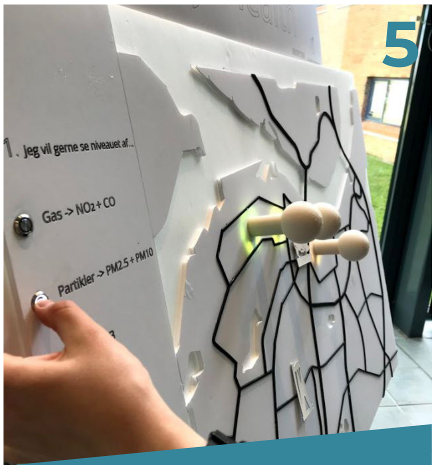
It is about city health in Aalborg, and she discovers that it visualizes different types of pollution; gas, particles, and noise.



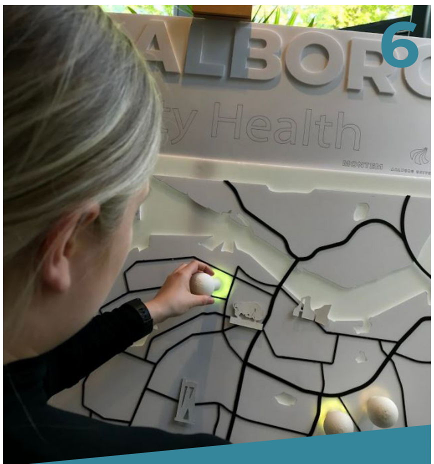
She thinks that the installation is interesting and starts exploring it by moving the pins around at different locations in the city.



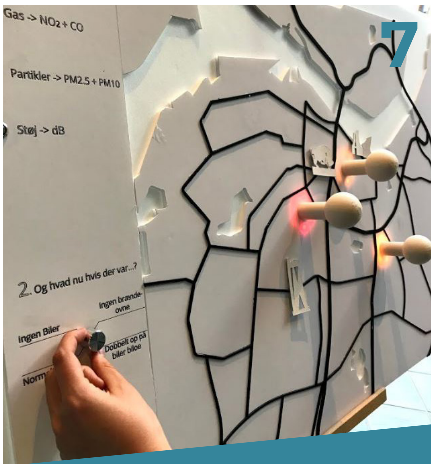
Now she can see the different levels of gas around in Aalborg and tries to place a pin in her residential area to see the levels here.



She chooses to see the pollution level of particles and discovers that the intensity is not as high as the gas level was.



She moves around the pins again to explore if there are other places in the city where the intensity is higher.



Afterwards, she modifies the map, to double the number of cars in Aalborg, and now the colors changes and the intensity increases.

She is now getting a bad feeling that the cars are playing a huge role in the pollution in the city and walks away with new knowledge.

Interaction scenario

Maria is typically studying at the library, and therefore spends a significant amount of time there during a day. Maria and her study group are about to take a break and head towards the water fountain in the exhibit room to refill her water bottle. As Maria fills the bottle, she notices the new exhibition "Aalborg City Health" and a map with pins attached to it. Maria goes to the map and starts reading the information posters on gas, particle and noise pollution around the map to get an idea of what the exhibit contains. Since it is a frequently discussed topic in her friend circle and the media, she decided to try and interact with the map. First Maria picks up the particle pollution pin, and wants to know the pollution levels at her study apartment and attaches the pin. The air quality seems fine according to the pulsating green light on the area around the pin. Maria takes another particle pollution pin and places it at the location her friend from the study group lives and notice the map around the pin starts blinking alarmingly with a pulsating red light. She then walks back to her study group, explaining what she has seen, and they go back to interact with the map, discovering different locations health levels. The interaction takes about 4 minutes as they also discuss the material shown around the PinMap while interacting with the map.

7.3.2 A full installation

An exhibition called "Maden mellem os", *see figure 7.7*, at Aalborg library, allowed the visitor to explore food and share their favorite food with other visitors. It contained information about people's food habits, recipes and information about different food experiences. The exhibition inspired us to setup the installation with literature relevant to city health, and this would give the users the information to further investigate the subject by themselves if they wanted to know more or make a change. An important aspect for the project group was that the installation had a social perspective to it and we wanted multiple individuals to be able to interact with the installation at the same time to create a shared learning experience and collaboration.

Figure 7.7: "Maden mellem os" exhibition at Aalborg Hovedbibliotek

The exhibition we would like to create consists of books, stickers and general information hanging around concerning pollution. *Figure 7.8* shows what the project group envisioned such an exhibition could look.

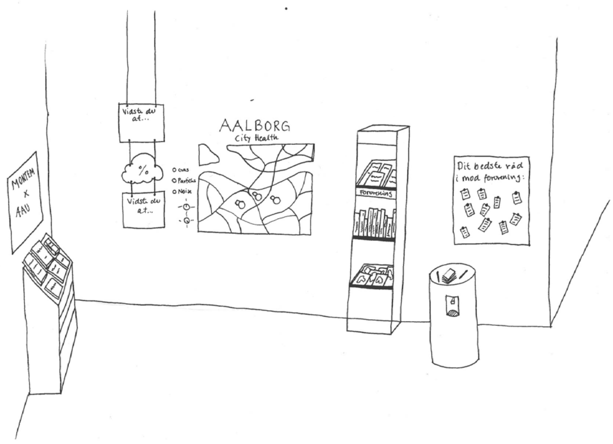


Figure 7.8: Possible setup for an exhibit at Aalborg library

PinMap would be the main attraction of the exhibition being centered at a wall close to the water machine. Around the PinMap there would be books themed around pollution, and what the users actively can do to reduce it as well as flyers they can bring home about the topic. The PinMap would also be accompanied by information on how we collect the data, and what it shows to enhance the understanding of the information displayed. Over the water fountain stickers would be available for the visitors to write on, the idea of the stickers is for the visitors to share their initiatives on fighting pollution with each other, the idea comes from the current installation at Aalborg Hovedbibliotek "Maden mellem os" which had posters hanging on the wall sharing the visitors favorite food.

7.4 Making of the third prototype

After refining the design of the PinMap installation, we started building the prototype. The purpose of the prototype was to evaluate it with users at the intended location, Aalborg Library. The project group wanted to build a high fidelity prototype to gain insights into how the design affects awareness through an evaluation.

The purpose of the prototype was to test how the users would respond to the map and to see how the idea would affect their awareness of pollution.

Because of limited time and budget, the prototype would not be built at a 1:1 scale with the design vision, instead we built a high fidelity prototype with some design features removed or altered. These technical limitations made it easier to construct the prototype while still maintaining the core functionality, another benefit of the limitations was that the time spent on research and testing was limited and there was more time to spend on construction.

Regarding the technical limitations, in the design vision, there was a pin for each type of pollution. The project group discovered it would be a technically complex task to do on limited time and due to the budget for the pins. Instead, users would have to select a type of pollution through buttons on a control board. For the same reason, it was not possible to add vibrations to each pin when placed on the map, as we had no idea which pin was activated at which time.

In the design vision, it was possible to place the pin anywhere on the map to get information about that area, but it would be too expensive and challenging to magnetize the whole map and then figure out how to display the data around each pin.

7.4.1 The general concept

The map consists of several smaller parts that make up the whole map, which will be detailed in the following sections.

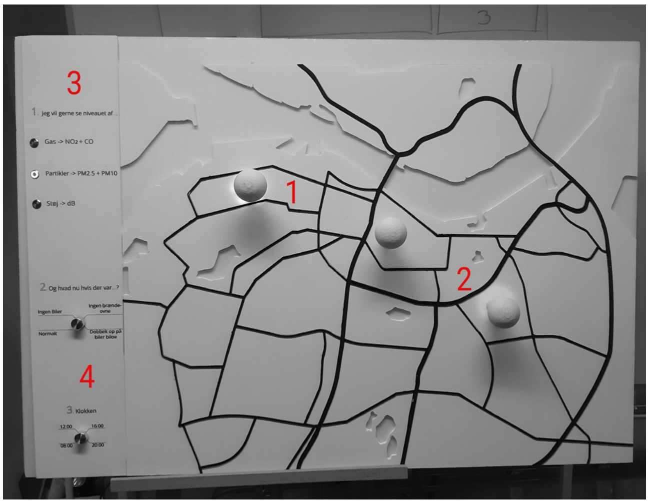


Figure 7.9: The final prototype. 1: Pin, 2: Pin location, 3: Control board with buttons, 4: control board with potentiometers

As seen in *figure 7.9* the front of the map consists of 4 major parts, the pin, locations, the buttons and the potentiometers on the control board.

The prototype functions like this. First, you pick up a pin and move it towards the map when the pin gets close to one of the 10 predetermined pin locations an led ring will begin to glow. This works by having a powerful magnet in the pin (number 1 in *figure 7.9*) and a magnetically sensitive switch in the pin location (number 2 in *figure 7.9*). When the magnet gets near the pin location, the magnetic switch connects the circuit and the microprocessor turns on the lights. Inside the pin location is a bent piece of iron that the magnet in the pin will be attracted to and then stick in place on the map.

At any time during this interaction the user can press the three buttons (no 3 in *figure 7.9*) on the control board or turn the dials (no 4 in *figure 7.9*) to change the data being displayed, this interaction will affect the data that the microprocessor uses to display the lights on the map.

7.4.2 The map

The map is the central part of the prototype, and it is where most of the interaction and attention is directed. Therefore it should also look like it is well constructed and should not look like an early stage prototype. The map was made from a piece of 5mm thick white foam core board on which a piece of 2mm thick black cardboard was overlaid displaying the roads of Aalborg. On the back of the foam core, a 10mm thick piece of hard white foam was placed to act as support. The white foam core is essentially a piece of foam sandwiched between glossy white carton.

With a CNC machine, the white foam core was cut into the shape of Aalborg city, including a part of Nørresundby and Egholm to create the outline of the fjord as described in section 7.2 *Design choices*. The black cardboard was then cut into a web of main roads in the city. This was done to make a precise and more professionally looking surface. As decided in section 7.2 *Design choices,* there had to be a sign that would help users identify the map, and this was also cut out in white foam core, to match the rest of the prototype, with the text “City Health”.

Pin locations

For the pin to stick to the map, and have somewhere to insert the LEDs, a pin location was designed in Solidworks. The pin location would work as a supportive structure to contain the LEDs, a magnetic sensor, and also a piece of metal. The reason for using a piece of metal to make the pin stick to the map was simply that the magnetic switch would always stay closed in the proximity of a magnet. Magnets magnetize some metals when in proximity, so both the magnetic sensor and metal would activate when a magnetic pin was nearby, and the pin would be able to stick to the map through magnetic force.

Through testing, it was found that not all shapes of the strip of iron were well suited to center a magnet in the center of the metal. It was found that the most reliable way to center the magnet was a bent strip of metal in an L form on its side.

7.4.3 The pin

The pin was modeled in Solidworks, and then 3D printed to quickly prototype it. The pin was printed in two pieces; a cylinder to contain a strong magnet and sphere to grab the pin by. The two pieces were assembled to get the shape of an oversized map pin. The pin was printed in white ABS plastic, and the white color made it fit the design of the map and avoid the pin taking away attention from the feedback displayed on the map. The use of ABS plastic made it sturdy enough to be dropped or fall off the map, which PLA plastic would not be strong enough to handle.

The cylinder measures 25mm in diameter on the outside and 21mm on the inside to fit a 20mm magnet. The length of the cylinder and the sphere both measures 50mm in diameter and is made with a 20mm cut to fit on the cylinder, *see figure 7.10*.

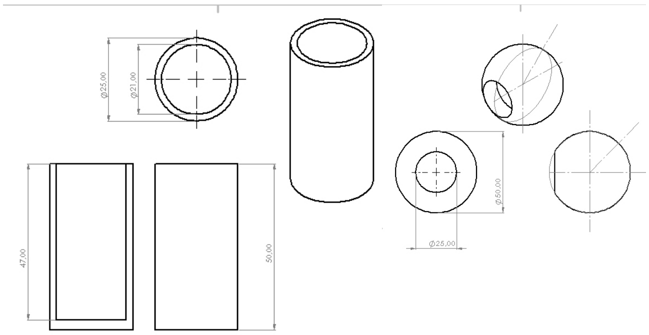


Figure 7.10: Technical drawing of the pin

7.4.4 The control unit

To make the map respond dynamically to the user's interactions, electronic components were needed. From the design vision, requirements were set; LED rings, rotating knobs, and some magnetic interaction. To control these components,ESP32 devkit v1 microcontroller with WiFi capabilities was chosen, as we had one already, *see figure 7.11.* The WiFi capability allows the prototype to connect directly to the city probe data and display near live data.

The controller also comes with 4mb flash memory and a higher clock speed than Arduino, making it able to react much faster to user interactions while running a complex program than the Arduino could.

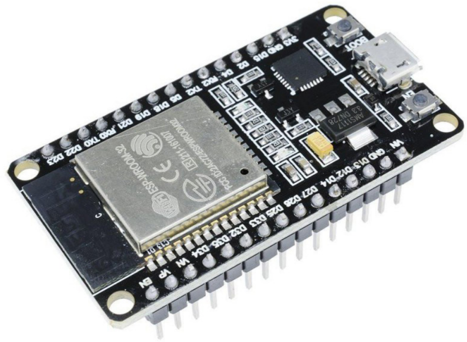


Figure 7.11: ESP minicontroler (JenTronic IVS, 2019)

The microcontroller's task in the prototype was to sense when any of the controlling inputs were changed and then download new data to display and then sense if any of the pins were placed on the map to the display that data with corresponding lights.

In the design vision, the user would be able to place the pin anywhere on the map, for the prototype we decided that this would be too complex for a prototype so instead, the project group opted to create 10 single locations that would be interactive. These locations were chosen in the city center and were spread enough apart, not to overlap. Doing this required 10 separate parts that the pin could react to, *see figure 7.12.* Each of these parts should contain LEDs, something magnetic and a reed switch to sense magnetism.

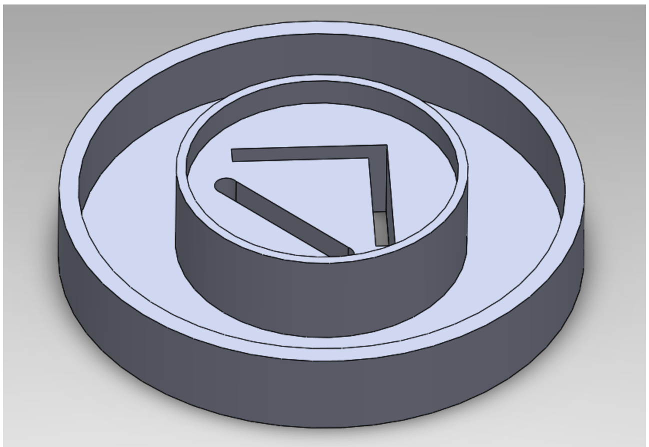


Figure 7.12: The part to hold the mechanical construction

Through testing, we determined that 6 LEDs would give the desired effect and the project group had to dig out some of the foam board backside to make the LED's shine bright enough while still bleeding into each other. Aluminum foil was applied to improve the effect around the edges so the light effect would be more pronounced. On the inner cylinder, 6 LEDs were attached with wires entering through the two holes on the bottom plate. In the inner cylinder, a 90 degree angle was cut through to insert a metal plate that would function as the magnetic material, and in the small slot with two holes a reed sensor was be mounted.

10 pin location mounts, *see figure 7.12,* wasprinted, assembled and connected to an ESP32 as well as two rotary potentiometers that would work as parameter modifiers and three momentary push buttons to select pollution type. As explained in the design vision, we wanted the pins to display one type of pollution each when placed on the map. However as we were unable to find a solution to this design choice, we opted for a three button selection instead so all pins would show the same type of pollution depending on which button was pressed. With that, the final schematic would look like *figure 7.13.*

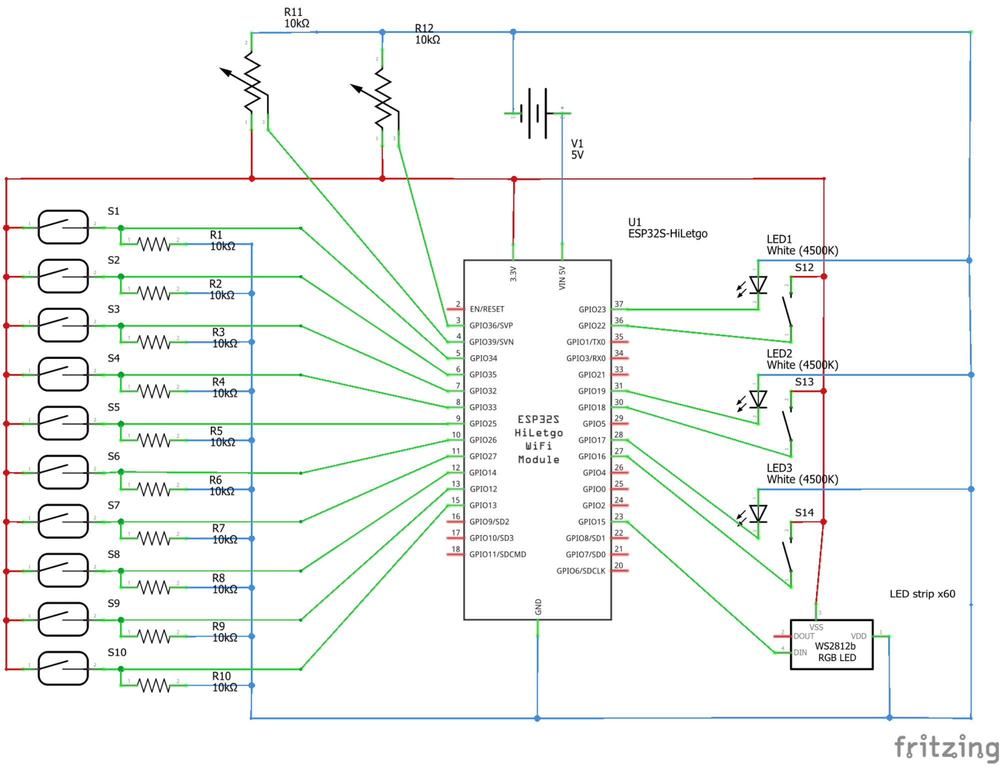


Figure 7.13: Schematic of the prototype

7.4.5 The hardware

Through the prototyping, several components have been used and in the following section descriptions of components and how they have been used will be elaborated.

For the pin location components, a strip of LEDs was used, the LED type was WS2812b, which is an LED strip with individually addressable LEDs. A row of 6 LEDs was used for each pin location component.
To sense when the magnetic pin is nearby a reed switch was used, which is a simple switch where two metal pins make contact when a magnetic force is nearby, allowing a connection to be made.
To make the control board, three momentary push buttons were used with built-in lighting. Two 10k potentiometers were also used, as *seen in figure 7.13*.

Modifier considerations

The Environmental Protection Agency of Denmark, as mentioned in chapter 1, *Background - section 1.3 Exploring the scope*, created limit values for different types of pollution. These numbers have been used to state when the level of pollution is harmful to the health. When the boundaries are exceeded, the LEDs will turn red on the map. Below is a diagram of when the different state of colors is met:

The **green** and slow pulsing light will appear when the level of:

- PM10 is < 25 µg/m3
- PM2.5 is < 12.0 µg/m3
- NO2 is < 25 µg/m3
- CO is < 8,999 µg/m3
- dB is < 29 decibels

The **yellow** and medium pulsing light will appear when the level of:

- PM10 is between 25 and 39 µg/m3
- PM2.5 is between 12.1 and 24.9 µg/m3
- NO2 is between 25 and 39.9 µg/m3
- CO is between 9,000 and 9,999 µg/m3
- dB is between 30 and 57 dB

The **red** and fast pulsing light will appear when the limit value is exceeded:

- PM10 is > 40 µg/m3
- PM2.5 is > 25 µg/m3
- NO2 is > 40 µg/m3
- CO is > 10,000 µg/m3
- dB is > 58 decibels

As mentioned in chapter 1, *Background - section 1.3 Exploring the scope*, wood burning stoves causes 67% of PM 2.5 particle pollution and 3% of nitrogen pollution, and transport causes 72% of nitrogen pollution, and 18% of PM2.5 particle pollution (Mst.dk, 2019 pp. 3).

When removing all the cars from the city, the pollution will decrease by 72% of nitrogen and 18% of the PM2.5. When the cars in the city are doubled up in the city, the nitrogen level will increase by 72% and the level of PM2.5 will increase by 18%. When removing all wood burning stoves in the city, the PM2.5 level will decrease by 67% and the nitrogen level with 3% (Mst.dk 2019).

These numbers are estimations and a way of visualizing how the levels of different pollution de- and increased based on the number of cars and stoves and used to simulate the large change and how the map would react.

Besides this, we have added a feature to choose four times throughout the day to see the data. The four times during the day are within the waking hours during a day, 8am, 12pm, 4pm and 8pm.

7.5 Presentation of Pin-Map

After all the design choices, construction considerations, and technical implementation, the high fidelity prototype was assembled, *see figure 7.14*.

In the next chapter, a user evaluation of the installation will be conducted and the findings presented.

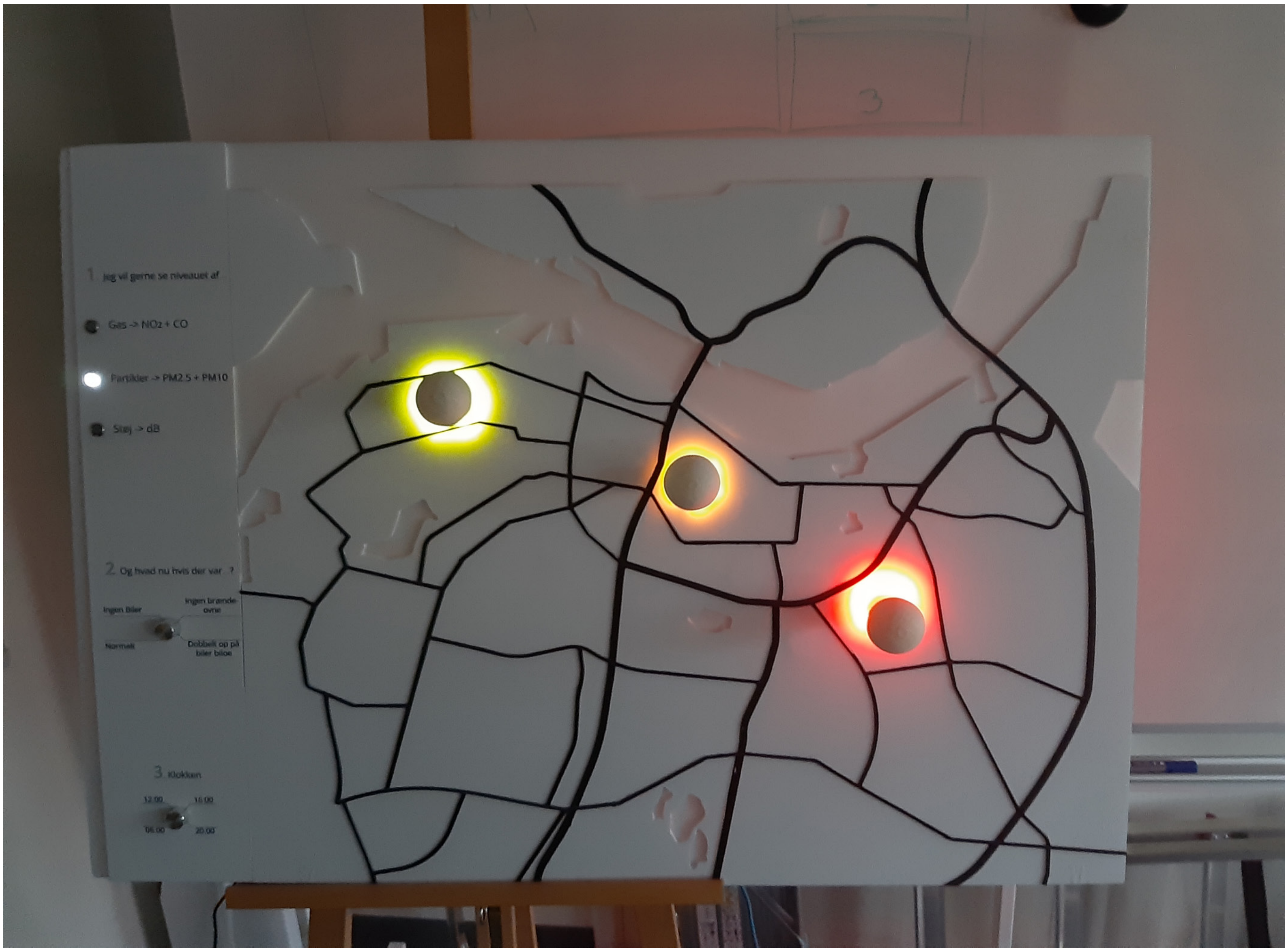
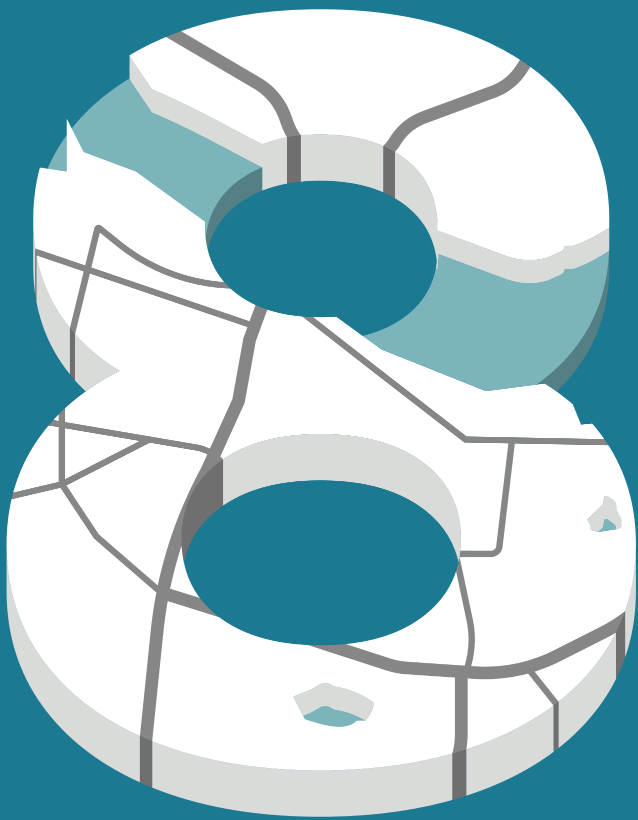


Figure 7.14: The finished high fidelity prototype

EVALUATION



After constructing the high fidelity prototype, a user evaluation was conducted to explore the interaction with the installation. The following chapter contains an overview of the user-based evaluation that took place at Aalborg Library. The evaluation was using observations and interviews, which will be explored and elaborated. Furthermore, the evaluation will be analyzed and concluded.

8.1 Preparation

To ensure consistent results from the evaluation, a structure was planned and followed. Based on the previous chapters, it was essential that the installation created awareness and gave the users insight into the initial problem pollution has on the environment. In addition, the project group wanted to get insights into how the users perceived the feedback, as their understanding was a key factor in creating awareness.

The evaluation took place at Aalborg Library in the exhibition area. We had a focus on creating a qualitative study, where semi-structured interviews and observation were the two main methods used. Through the observation, the project group wanted to explore if the users would interact with the installation, without the project group being around, to see how they arranged themselves in the environment and to observe if they could use it without the need of instructions.

To create awareness and an experience for the users, O'brian and Toms "Model of engagement" was explored. In the article "What is user engagement - a conceptual framework for defining user engagement in technology", Heather L. O'Brien and Elaine G. Toms explore users' perception of being engaged with technology. From this study, the results indicated four steps of engagement, which was point of engagement, period of sustained engagement, disengagement and re-engagement (L. O'Brien and G. Toms, 2008). These four steps were made into a conceptual model, based on the attributes the users inherited at each step in the process of research, *see figure 8.1* (ibid.).

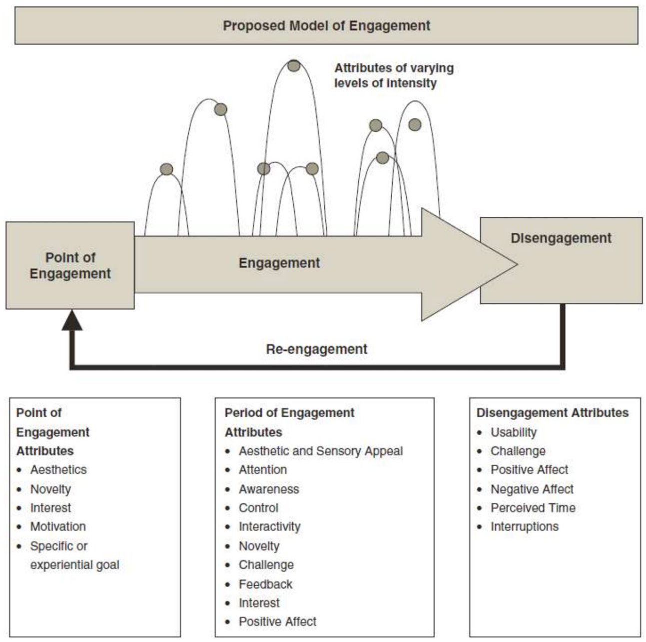


Figure 8.1: A conceptual framework for defining user engagement in technology (L. O'Brien and G. Toms, 2008)

The model was used to gain insights into how the users felt about the overall experience of the installation. The three steps of engagement were printed on paper and the project group wanted the participants to draw a circle around the attributes they found fitting for their engagement with the installation.

The evaluation followed a four-step plan, where the first step was to recruit users. The project group wanted participants that fitted within our two personas to interact with the installation, as mentioned in chapter 7 section 7.1.1 *Target group.* The next step was to interact with the map, followed by an interview about the map and lastly a debriefing session.

The main purpose of the evaluation, was to explore if the users understood the feedback and whether they became aware of the problem. The questions in the evaluation were oriented towards understanding these aspects.

The questions were:

"Do you understand the meaning of the colors and the flashing lights?"

"What feeling did you get from seeing the pollution? - Did you get something out of it that you did not expect?"

"Do you feel new enlightenment regarding pollution?"

8.2 Evaluating with users

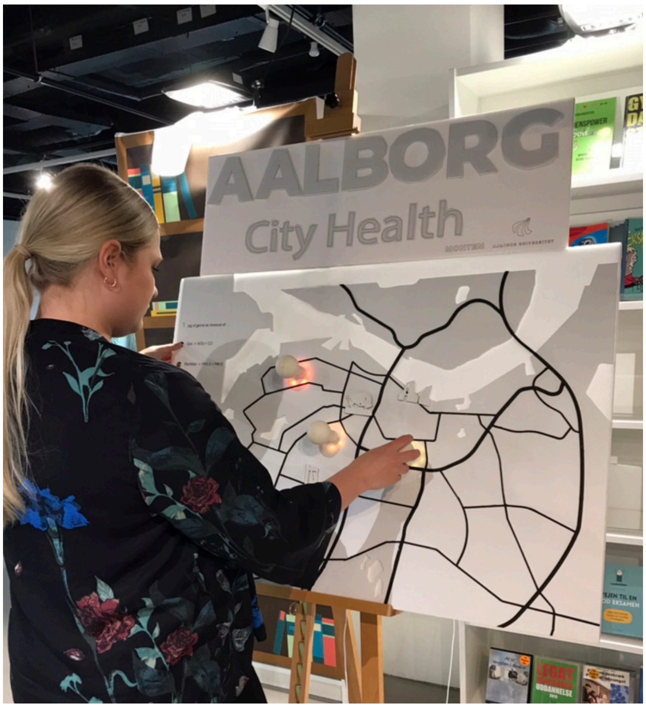


Figure 8.2: The installation in use.

The project group evaluated with three individual users, two groups containing two users and one group of three users. The users interacted with the installation, while a facilitator was standing nearby, *see figure 8.2.*

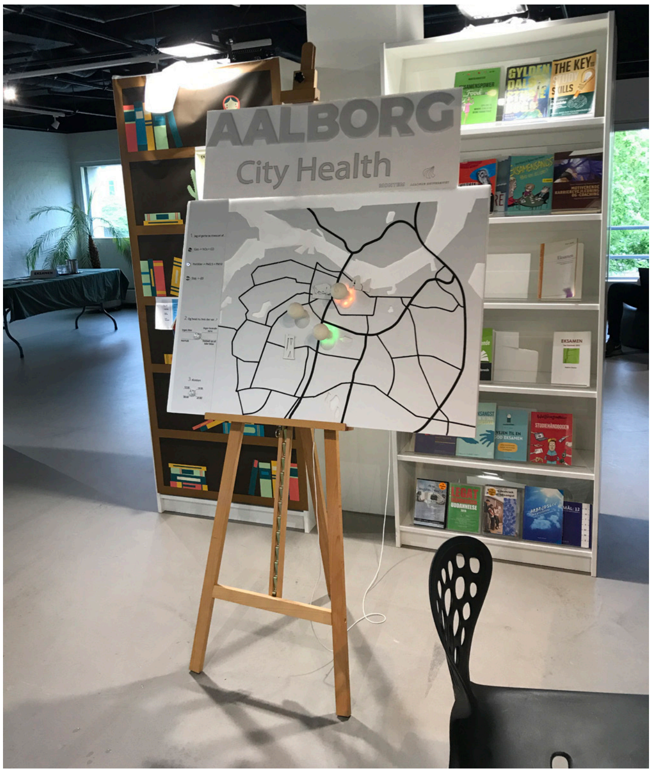


Figure 8.3: The installation placed in the exhibition area

Throughout the evaluation the facilitator performed a semi-structured interview, while another project member took notes and lastly one project member who observed. The project group was interested in observing the participants facial expressions when interacting with the installation. These observations could give indications on their emotional experience through the interaction. The installation was placed in the exhibition area and when the visitors entered the library, they would have a clear view of the installation, *see figure 8.3 and 8.4.*

Figure 8.4: The installation seen from a broader view

The project group found it interesting to explore how groups of people would arrange themselves in relation to the installation. In the evaluation the project group explored how F-formation occurred, while groups were interacting with the installation. When people are engaging in a conversation, they often occur in a spatial orientational arrangement (Den, Y. 2018). It was important that the users had equal and direct access to the installation.

It was therefore interesting to observe how the participants in the group interacted with the installation, through their spatial relationship (Profs.scienze.univr.it, 2019).

F-formation contains three different social spaces, these being O-space, R-space and P-space, *see figure 8.5* (Profs.scienze.univr.it, 2019). The O-space is an empty space surrounded by people involved in social interaction, whereas the P-space is a more narrow space where people are standing, surrounding the O-space. The R-space is excluded from the other two spaces and includes everything outside the O- and P-space (ibid.). The project group's goal was to find the O-space. F-formation occurs when people are grouping, and there are different configurations. Two participants can create a vis-a-vis orientation, L-shape and side-by-side. In the case of a higher number of participants a circular formation is formed (ibid.).

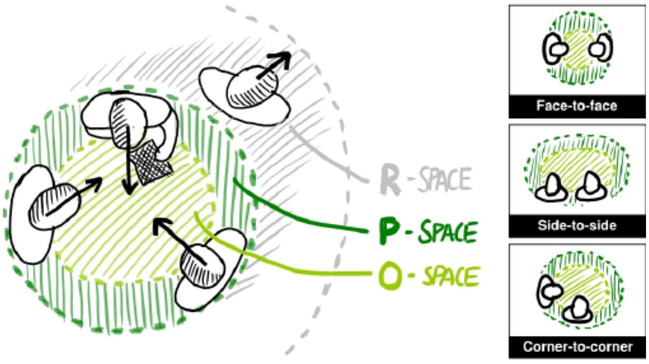


Figure 8.5: F-formation of social spaces (Profs. scienze.univr.it, 2019)

8.3 Results

After conducting the user evaluation, the project group analyzed the data from the observation, the exploration of the map and the belonging interview. The data was coded and clustered into categories to get an overview and to identify patterns from the evaluation. The following analysis was divided into two sections; the observation and the exploration of the map.

8.3.1 The observation

Observing the installation, twelve users were seen interacting with the installation to some degree. Six of the twelve users that interacted with the map only looked at the different modifiers on the left side of the installation. It caught their eyes and they walked a bit closer to get a better look, but they did not interact with the installation. They were not within close proximity, due to them standing about 1.5 to 1 meter away from the installation, which resulted in users barely being able to read what was written on the installation.

Four out of the twelve users observed, went straight for the installation, and started pushing different buttons and tried out the modifiers. None of the users tried to interact with the tangible pins, as the users did not know the pins could be moved around and thought it was a static part of the map. Observing the four users, there was a much closer proximity between the users and the installation, which made it possible to modify the parameters and see changes in the pollution.

The last four users would look at the installation from a distance, they did not interact with the installation, but acknowledged there was an installation.

One group, a mother and child, walked up and used the installation while the project group was observing. The mother told the child what to do and the child pushed the buttons, while the mother read aloud from the installation. They had a side-by-side f-formation when facing the installation, but the mother let the child stand slightly in front of her, to make him in charge of the interaction.

The observations indicated that the installation, at this point of the process, was not a "walk-up-and-use" installation. The users knew that it was an interactive map, but did not know how to use the pins to see different locations and therefore, only received information at three locations. Based on these observations there was no indication that the users understood the feedback or became aware of the problem. From their facial expressions, they looked a bit surprised and the mother and child, expressed to each other that it was about city health and pollution in Aalborg.

8.3.2 Interview and exploration of the installation

When analyzing the data from the evaluation of the installation, some clear patterns emerged. Based on the goals the project group had for the evaluation and the structure made ahead of it, the analysis was divided into seven sections; feedback, pins, awareness, emotions, engagement, f-formation and the holistic experience.

Feedback

Six out of the six users at the evaluation understood the feedback as intended. They knew that the green color was representing low intensity of pollution, the red color represented the highest intensities, and the yellow being in between. One of the users expressed that the red color represented a high concentration of pollution and when she used the modifier to double up the cars in Aalborg she stated "Oh boy, that is a lot of pollution". Furthermore, all the users expressed that the feedback was easy to understand.

One user expressed that he would like to have something to compare the colors to, such as a color scale to see the different shades of colors. The user stated that he needed something to compare the colors to, to know more accurately how much pollution it was.

Pins

The users found the tangible pins fun and many were surprised when they experienced that it was possible to move them around on the map. The users expressed that it was explorative to move them around and see the differences in the intensities at different locations. One of the user stated “Oh my god, that is cool!” when she experienced that the pins were moveable, and right away she took one herself and started to explore the map.

Awareness

One of the users tried out the modifier to remove wood burning stoves and he got astonished over the decrease in particle pollution. He was not aware that it had such a significant effect on the particle pollution and asked several times

“Are they really that bad? Also when I am using dry wood? I do not hope my wife finds out, she will be mad when i tell her how polluting it is”.

Another user got surprised about the levels of pollution in her residential area, especially since she has chosen to live outside the center of Aalborg. She liked that it was possible to see the pollution levels on a local level in her city and said

“You hear alot about it in the media, but it is a lot more fun to see it more locally”.

After interacting with the installation she felt informed and aware of the levels of pollution in the area where she lives.

One user expressed that she knew there was pollution in the city, but she did not use much time thinking about it. She thought that the installation informed her well, on how much pollution there was in the city. However, she thought she would need more information to get an idea about how to minimize pollution. She said

“It is a too huge restructuring to get rid of cars and a wood burning stoves”.

She would like to know more about the little things she could do in her everyday life that did not include to get rid of her car. Among this, she only understood the parameters, *gas, noise and particles*, because the project group explained it to her and she would have liked to have some additional information regarding these.

Emotion

Four of the six users expressed that they did not like to see the red color and one user even got sad to see the conditions of the health in Aalborg. One of the users said

“It does not look good, we should do something about it”.

The installation left the users with a feeling of a need to do something, but without the installation telling them what they should do, they were left to decide by themselves. However, one of the groups that evaluated the installation, expressed that they did not like to see that many red lights in the city, but that they did not get any emotional response from it.

Engagement

The users filled out the engagement scheme after the interview, where the facilitator guided and explained the purpose of it.

The point of engagement was motivated by the aesthetically look of the installation, which attracted the users to engage with the installation. Another reason the users wanted to engage with the installation was based on their interest in the subject and because they had a personal interest in it.

To keep up the engagement after the point of engagement has occurred, the users expressed that the period of engagement was motivated by the awareness and information they received. They would keep engaging because the installation was interactive, novelty and challenging. However, one user expressed, that she would not stay engaged if she had not had any help from the facilitator.

The users will disengage after they experienced all the different modifiers and when there was no more to learn. A user expressed that she would disengage when she had seen all the parameters in her residential area, however, she said that the pins were so fun that she would probably explore more of the map after seeing her own area.

F-formations

As described in section 8.2 *Evaluating with users,* the project group wanted to observe the users' f-formation in relation to the installation, with the goal of finding the O-space.

A pattern, that occurred several times when evaluating with the groups of two or more users, was the side-by-side formation where the users were standing shoulder by shoulder to each other, and with the installation in front of them. With this orientation, the space between the group and the installation became the O-space, *see figure 8.6*. The orientation to the installation was not full frontal facing, since they were often standing a bit obliquely to the installation, and almost forming a L-shape. It repeatedly occurred that only one member of the user group was interacting with the installation and therefore was standing a bit in front of the others. This disrupted the dynamic of the interaction and made the users behind a lesser part of the experience, as they could not contribute as much to the interaction.

The holistic experience

The users generally expressed that they thought the experience of using the installation was exciting and enjoyable. The users stated that the installation was aesthetically pleasing and that the construction of

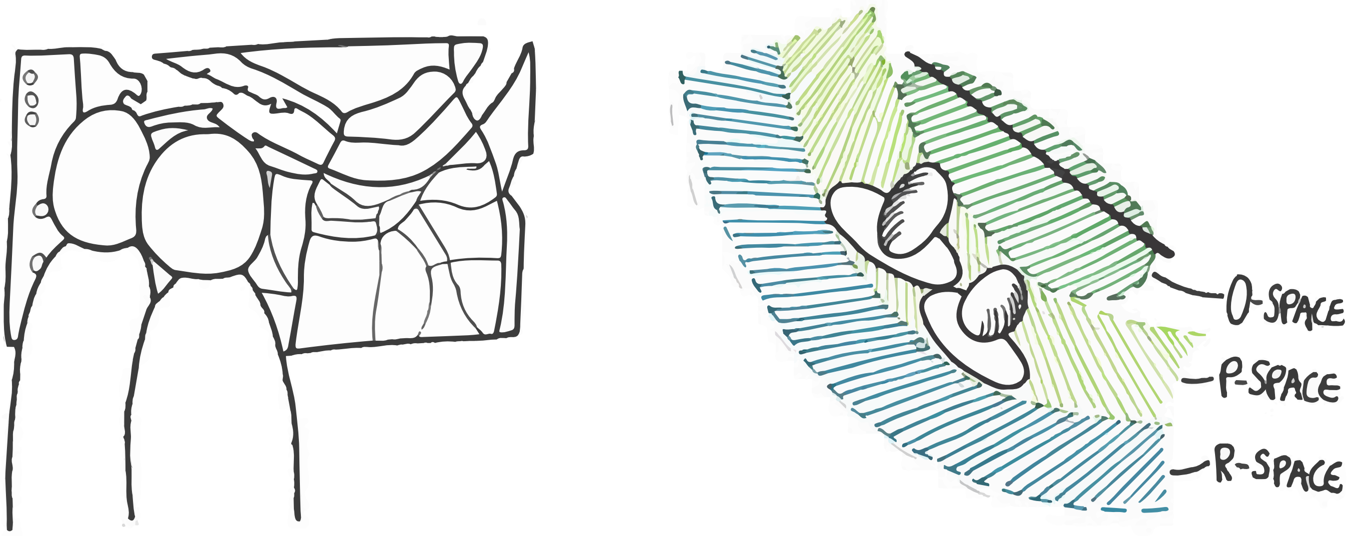


Figure 8.6: Visualization of the installation's f-formation (Profs.scienze.univr.it, 2019)

it was done well. Furthermore, the installation was easy to use and understand, and the attractions of Aalborg made it easier for the users to navigate the map.

8.3.3 Summary of the findings

Through the findings from the evaluation, there was a strong indication that the users clearly understood the feedback and the interaction with the map. They quickly perceived the feedback and were able to associate the colors with the intensity of pollution.

From the observation and the users' expressions, when they saw that the pins were moveable, it was indicated that the pins did not look like a tangible object to interact with and move around.

The installation made the users aware of the pollution and informed them of pollution levels in their city. It was only apparent to a few of the users that the modifiers changed the effect the cars and woodburning stoves had on the environment. The users needed something more specific to relate to, which did not require significant changes in their everyday lives, to help minimize pollution. This indicated that the installation did not inform the users upon how they could contribute to lower levels of pollution in Aalborg, but only made them aware of the sources that were contributing to the pollution.

The users were emotionally affected by seeing the high levels of pollution, and knew they had to take action, but did not know what to do.

The engagement scheme indicated that the users started engaging with the installation based on their interest within the subject and because of aesthetic appeal. The users kept on engaging because it was interactive, novelty and because they received new knowledge and awareness on the subject. The users stopped the engagement, when they had tried all the interactions on the map, and when they had received the necessary information.

From observing the users f-formations, the project group observed that the installation was within the O-space of the interacting users. Unfortunately the installation did not support interaction with several users at once.

DISCUSSION

This chapter consists of a discussion and reflections upon aspects that could affect the outcome of the project. Considerations regarding the design process, user involvement awareness, location and recruiting users will be explored and elaborated.

9.1 Involving stakeholders

Since the project has been focusing on creating an experience of the citizens of Aalborg, the users of the installation have been the only stakeholder that has been involved in the process. It could have been interesting to involve other stakeholders, such as experts from the university that are working with the City Probes. These stakeholders would have had a more in depth insight and knowledge about how the data should be read. It could have been interesting to involve their considerations regarding the information provided to the citizens, and even hear out their ideas for a solution.

Another stakeholder that was considered to involve in the process was the Aalborg municipality. It could have been interesting to present the idea for them in order to figure out if it was a service they would like to provide to their citizens. They would properly have an opinion on what the citizens should be provided.

Throughout the project the focus was on creating an experience for the general population of Aalborg, and therefore, their opinions had significant importance during the project.

9.2 User involvement

At the beginning of this process, guidelines were made in collaboration with MONTEM. Through these guidelines two iteration rounds were made, which in described in the chapters 4 and 5, The first prototype and The second prototype. Users were involved in the third prototype, which gave us insights into their thoughts on the initial problem. An interesting approach on this project, would be, if users were involved in the early stages of the design phase. Involving users early on, would have allowd us to Co-design with the users, and get an insight into their thought and ideas for a solution, this would have an importance of the final installation and have given us a clear argumentation of the choices made for the design. It could have been beneficial to use a co-design tool to facilitate such involvement. For example, an inspiration card workshop as a collaborative method to facilitate co-design, where different cards were used to create new concepts of design could be used.

On the other hand, the focus of this project was to create awareness and ensure that the users would understand the provided feedback. Since we were designing an experience desired from a design case, and not from the need of the users, the project group took the freedom to develop an idea in collaboration with MONTEM without involving the users. Users have on the other hand, been testing our ongoing design choices, to get insight into their way of perceiving information and also to hear out their opinions. The users have been a part of the ongoing process, but the chosen concept was not anchored in the users wants and needs.

9.3 Location

The location for the installation was explored later on in the process. An advantage would have been to determine the location early on in the process, so it would have been possible to design for the location and the specific target users. On the other hand, an advantage for choosing the location later on, allowed us to design an installation for the universal room. Without the predetermined location, the design of the installation could be moved around at any location, and thereby reach the general population of Aalborg.

9.4 Recruiting user

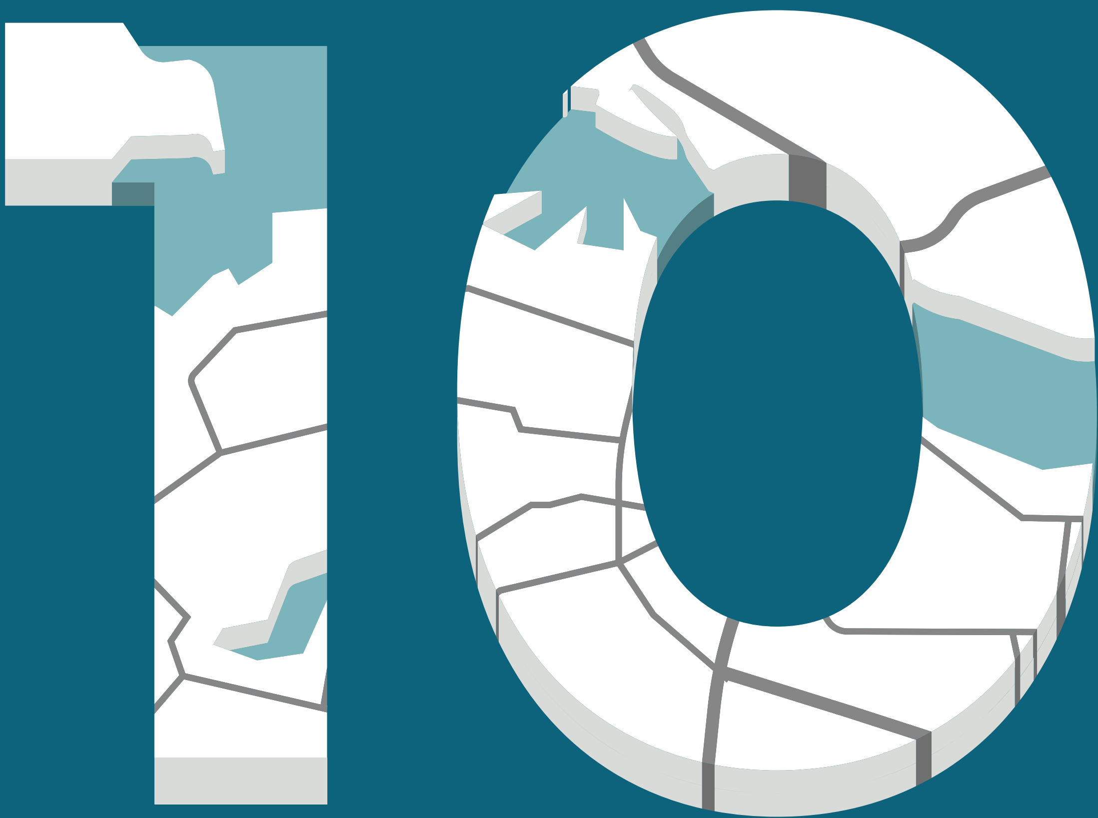
When testing the first and second prototype we used participants from the university. Since these tests mostly were to gain insight into their perception of the map, the pins and the feedback, we did not co-design with them, but only tested specific parts of the prototype. A disadvantage for recruiting participants from Aalborg University, might have been, that the participants had a previous knowledge when interacting with the prototype. This could have been given us biased results. Another aspect to consider was that users from Aalborg University were within the same segment. They were all students in the same age group and it would have been interesting to investigate if users outside this segment also would have perceived the feedback as intended.

Based on the available resources, the project assessed that it was more important to focus on getting fast results to move on in the process, than spending time recruiting different users.

9.5 Can we create awareness?

An exciting aspect to discuss regarding this project, is the level of awareness the installation provides. A question to ask, is if the users really became aware when interacting with the installation. The majority of the participants interacted with the installation for approximately 2-3 minutes. A discussion arose after the evaluation regarding if the installation itself were enough to create awareness. It would have been beneficial to create some information about pollution and the effects it has on the environment today. Through this information it would perhaps have created a more specific awareness about the initial problem. Another interesting aspect to consider, is when the users have interacted with the installation and have become aware of the problem, would the installation then become regardless. On the other hand, the installation visualizes live data, so there will come a point when the users will reengage with the installation, if they are interested in getting new knowledge on pollution levels on that specific day.

CONCLUSION & FURTURE WORK



The objective of this project aims to design a spatial visualization of data and to create an awareness about the effects pollution has on the environment in Aalborg. To create a direction and scope for this project, a meeting with MONTEM was arranged, and additional research was explored. Throughout this research, it became clear that air and noise pollution are two of the most significant factors in damaging the environment. To narrow down the problem domain within this project, the following problem statement was made:

"How can we design an installation that creates awareness on pollution, that is easily understandable for the general public of Aalborg to interpret their everyday environment, by using spatial visualization methods that communicate informations about city health."

The outcome of this project was an interactive installation called PinMap, which focuses on creating awareness about pollution for the general population of Aalborg. The installation provides the users with an overview of pollution levels for three parameters; *Noise, Gas, and Particles* at specific locations in Aalborg. Three tangible pins can be moved around on the map, and at the selected locations, the users will get feedback in the form of pulsating colored light depending on the level of pollution. With this installation, users have the ability to gain knowledge about the levels of pollution in the city and the leading cause for these levels.

Based on feedback from the evaluation the project group could conclude, there was an indication of users becoming more aware of pollution in the local area. When interacting with the installation, it was easy for the users to understand the feedback provided by the map. The evaluation also indicated the installation was not a walk-up-and-use installation as the project group intended.

10.2 Future work

This section consists of considerations regarding elements that would be interesting to implement in future work.

If the development of the installation proceeded, it would be beneficial to evaluate with several more participants which we would assume would give more specific results and a clearer insight into the experience and the problematics with the installation. Among this, we would make an in-depth evaluation with an expert such as a museum inspector or Visit Aalborg. This could give us insights into the installations in general and knowledge about the relevance for the general population in Aalborg and tourists. Having an expert evaluation might give us specific results that users might overlook or, and it could be used to strengthen our design.

Another interesting thing to consider for future work, is the expansion of the map. The installation only focuses on a specific part of Aalborg, where the CityProbes are located. If more CityProbes are to come in the future, then the installation would be expanded, so the users have a larger area to interact with.

As described in the analysis of the evaluation, the installation was not a "walk-up-and-use"-installation in a sense that none of the visitors we observed moved the pins around. However, the visitors showed interest in the product and understood how to change the parameters. To enhance the interaction, it could be interesting to include a step by step poster to give instructions on

how to explore the map.
Due to time and limitations, it was not possible for the project group to create a library exhibition with the focus of surrounding the installation with books, facts and pictures of pollution in Aalborg. This will be a prioritize in the future, because it will be very interesting to see if the surroundings could affect on how the users perceive the installation. It would be interesting to see if it would contribute to their awareness of pollution and if it could give them a knowledge of which they could do them self to help minimize it

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